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GUIDE TO

CAMOUFLAGE

FOR

DEVELOPERS

VOLUME II

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ROLE OF CAMOUFLAGE

A-1 INTRODUCTION

The purpose of this Appendix is to set forth important aspects of the role of camouflage with respect to its use in enhancing the survivability and effectiveness of systems on the battlefield. The discussion includes theories affecting camouflage design, considerations for visual acquisition, measures of effectiveness (MOE) for camouflage, factors involved in differential MOE of camouflage, and concludes with target acquisition considerations. [illegible] countermeasures; infrared countermeasures; [illegible] camouflage, electro-optical countermeasures (EO) [illegible]

A-2 THEORETICAL PRINCIPLES AFFECTING CAMOUFLAGE DESIGN

Tactical elements that reflect or radiate unique colors or intensities obviously advertise their presence on the battlefield when appropriately viewed and/or radiated. Any paint or finish that fluoresces under some irradiation would instantly reveal itself. Obviously, the designer must make sure that none of the surface finishes have such properties. He should also make certain that the intensity of reflectance or spontaneous emission should not uniquely attract target acquisition observation. For example, a surface that is completely black to microwave radar may, by contrast with the background, silhouette the defending element and actually could increase the probability for being acquired by target viewing observation techniques.

A-2.1 Form Recognition.

By and large, the most common manner of target acquisition is through observer recognition of the form of the viewed image. It is for this mode that most theoretical progress has been made. The theory applies to viewing technologies that present a visual image to the human observer (or in the most sophisticated applications, to a target pattern recognition system automated into computer-artificial intelligence targeting systems).

The technical measure utilized is the limiting resolution of the viewing equipment/observer system. This resolution may be expressed as the angle, α, in radians, subtended by the arc of the limiting resolution. For a viewed target at a distance of R meters, the cross-sectional width of the minimum resolved band W is given by R meters.

$$W = \alpha R$$

Another way of expressing the resolution is in "lines," L. The number of lines, L, of resoluton over its image of the target is defined as the ratio of the width, D, to the size of the minimum resolved band width.

$$L = D/W = D/\alpha R$$

For example, a target with significant dimension D = 2 meters, at a range R = 4000 meters viewed with a system having a resolution, α, of 2.5 X 10^{-4} radians, yields a line resolution L:

$$L = \frac{2}{2.5 \times 10^{-4} \times 4000} = 2 \text{ lines}$$

Under these conditions, the target would appear to the system/observer such that features of 1/2 the dimension D would be discernable. That is, the vehicle would appear as a discernable blob with just the suggestion of shape. An observer/system discrimination of 2 lines has been determined to be the limiting resolution permitting the observer to conclude that the viewed object in a field of low clutter is of military significance (this is the definition of target detection) with a probability of one-half (see Table A-1).

Table A-1. Definition of Levels of Target Acquisition and Estimated Line Discrimination Required.

LOW BACKGROUND CLUTTER, NO CAMOUFLAGE

NAME	EXAMPLE	LINE*	MINIMUM FEATURE RESOLUTION**
DETECTION	MILITARY VEHICLE OR BLOB	2.0	1.5 METERS
ORIENTATION	END OR SIDE VIEW	2.8	1.07 METERS
CLASSIFICATION	TRACKED OR WHEELED VEHICLE	5.0	60 CENTIMETERS
RECOGNITION	TANK OR APC OR ADV	8.0	35 CENTIMETERS
IDENTIFICATION	M60 OR T62	12.8	23 CENTIMETERS

* 2 Lines is one cycle of one black, one white line.
Measure per critical (minimum) dimension.
** For a target 3 m on a side.

As minimum range of detection is defined, that range at which the viewing conditions of detection of the target is discriminated with a 50% probability to be of military significance.

A-2.2 Background Affect.

A moderate amount of experimentation has demonstrated that the presence of background clutter reduces the probability of detection -- or conversely -- requires a higher level of discrimination resolution to enable detection. The following estimations (Table A-2) have been published by the NV & EO Laboratory.

Under conditions of these experiments, the background contained dark/light undulations that masked the detection acquisition based simply on the presence of a blob -- there may have been already too many similar blobs in the background clutter to enable the selection of a militarily significant blob with a probability of 50%.

Table A-2. Detection Resolution Requirements, No Camouflage, for Variable Levels of Background Clutter.

CONDITION	RESOLUTION, LINES
No clutter (aircraft against a sky background)	<1.0
Low Clutter (Target in Field, on road)	2.0
Target in "Medium" Cluttered Field	4.0
High Clutter (e.g. ZSU-23 in Array of T-72's)	6.0

This table is significant in that it demonstrates that in the presence of clutter obscuring the gross detail (2 line discrimination) by presenting a background of many features (blobs) indistinguishable from the significant blob, the military vehicle, that the viewer must move toward increasingly finer features in order to distinguish background from target. In the last case, High Clutter, the viewer almost has to move in to get a resolution better than that for classification to get features of the target significantly different than those of the clutter -- in the extreme case, one would need the viewing for identification or better to "detect" a T-72 Mod 1 from a T-72 Mod 3, if the latter is one in the middle of several of the earlier Mods.

A measure of the effect of clutter is then the number of additional lines of resolution over that with low clutter needed to allow discernment at the detection level.

The literature is vague about the theoretical effect of camouflage and almost non-existent about the combined effects of camouflage and clutter. There are arguments on both sides of the question whether the resolution requirements are disjunctive (i.e., one or the other; take the worst case) or additive. In the absence of firm theoretical or experimental clarity on this question, it is recommended that an engineer designer take a conservative position:

Defensive: For the design of camouflage, assume the effects of camouflage and of background are independent; use the greater one leading to the greater requirement.

Attack: For the design of target acquisition technology, consider that the resolution requirements are additive.

In Figure A-1, this engineering policy is illustrated. In Table A-3, the relationship of estimates of the maximum ranges for target acquisition at the conditions of detection, recognition, and identification are displayed for various conditions of clutter and with and without camouflage.

A-2.3 Recognition and Identification in the Presence of Camouflage and Background.

Camouflage is meant to conceal totally -- as in the use of camouflage nets to cover a vehicle and to appear from a distance as more background. Camouflage paint (for visual deception) and similar external skins (for deception to other acquisition devices) that are organic to a mobile vehicle or unit are meant to break up the image with skin coloring and lines in such a manner that the observer-target acquisition process is confused in target perception. The question addressed here is this: When a vehicle is painted with a standard camouflage pattern that reduces the maximum range of detection by one-half; what change is produced in the maximum ranges for target recognition and identification, and how are both affected in the presence of "high" background clutter?

The theory and experiment are both incomplete with respect to these questions. In the first place, the maximum ranges for 50% acquisition at the recognition and identification level are from 1/4 to 1/7 the maximum range for detection. Therefore, the experimental determination of these ranges has to be carried out with correspondingly greater precision. Precise measurements then may require experiments numbered in the order of the square of the precision ratio; i.e., from 16 to 50 times the number of experiments in order to afford relative accuracy as precise as that determined for detection. The experimental determination of the maximum range for 50% probability itself requires that a significant portion of the whole range versus probability of acquisition be measured. Even this magnitude of measurements leaves many parameters whose variation needs to be examined. Lighting, background, season, terrain, acquisition technology, camouflaged object, camouflage parameters

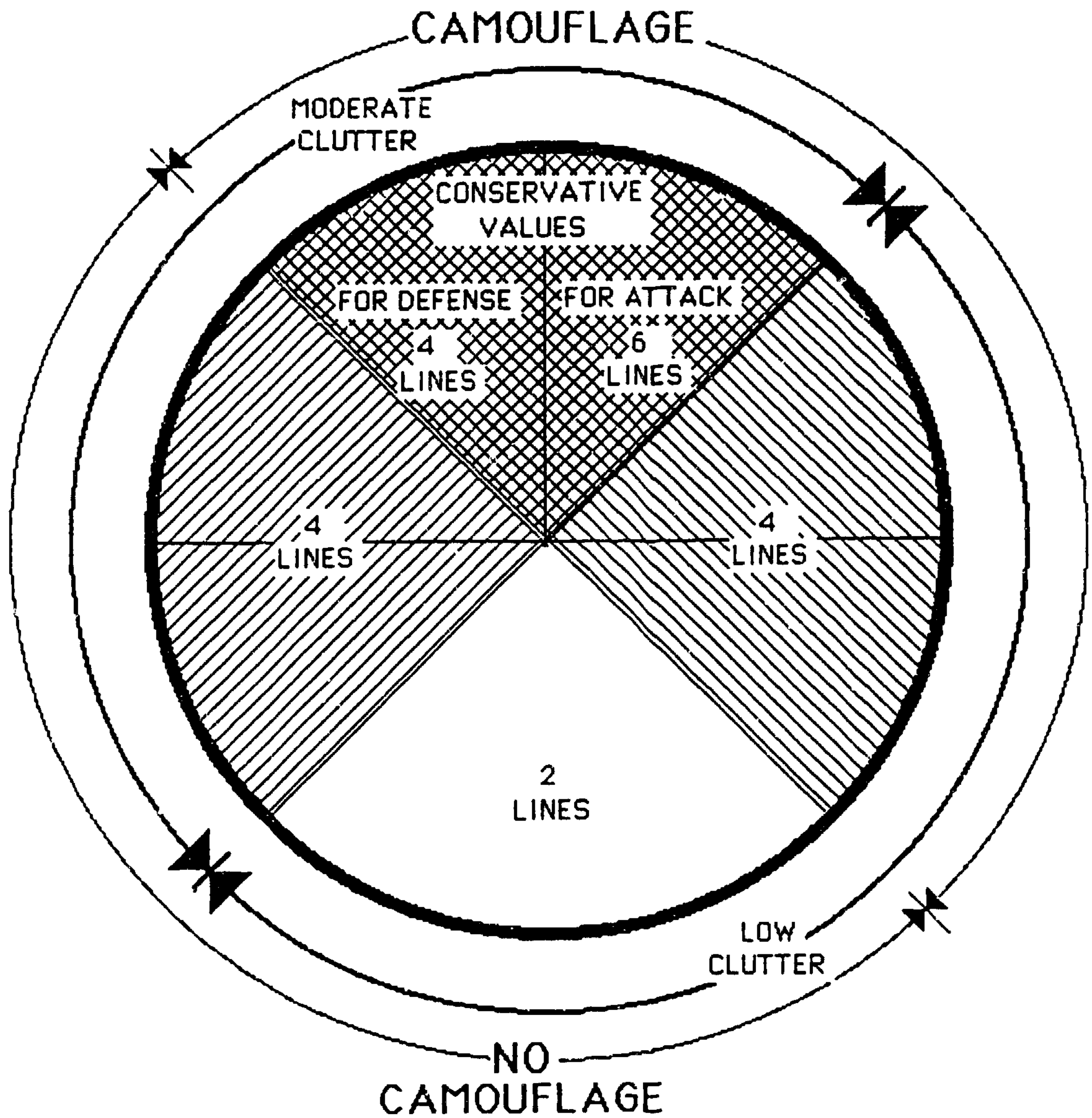


Figure A-1. Resolution Required for Detection With/Without Clutter and With/ Without Camouflage.

Table A-3. Representative Maximum Ranges for Target Acquisition

No Clutter No Camouflage	Low Clutter No Camouflage	Moderate Clutter With Camouflage	Moderate Clutter With Camouflage — Conservative Estimate for: Defense	Moderate Clutter With Camouflage — Conservative Estimate for: Attack
Detection				
1.00 Lines 8.00 km	2.00 Lines 4.00 km	4.00 Lines 2.00 km	4.0 Lines 2.00 km	6.00 Lines 1.33 km
Recognition				
7.0 Lines 1.14 km	8.0 Lines 1.00 km	10.0 Lines 0.80 km	10.0 Lines 0.80 km	12.0 Lines 0.67 km
Identification				
11.0 Lines .68 km	12.8 Lines .63 km	14.8 Lines .54 km	14.8 Lines .54 km	16.8 Lines .47 km

(pattern, color, etc.). The determination of answers to the question immediately balloons out of all proportion. To date, experimental data over the range of all of these parameters are very sparse. Such data as do exist require comparison among experiments that are insufficiently controlled. Some experiments suggest even that there is insignificant changes in the maximum ranges for recognition and identification under conditions that change the maximum range for detection (read: "at the 50% probability level" in all of the above).

With respect to recognition and identification, there is another consideration: the ranges for these acquisitions are from 1/4 to 1/7 of those for detection. An attacker, suddenly popping up over a hill (as an armed attack helicopter or an IFV) may acquire several targets. Those that are nearest will present the greatest threat and immediately become the targets of preference; since any weapon they have for fighting back will have the shortest reaction times; and gun-type weapons will have a relatively greater lethality than those at greater ranges.

Furthermore, any targets detected (and not recognized or identified) have already lost their most valued defense -- anonymity -- and can be remembered for later investigation by suitable tactical maneuver.

While theoretically there are advantages to the attacker to identify and select those targets that are the greatest threat to him for his attack, the time factors are so sensitive that, in the heat of battle, he will tend to select the nearest and most obvious targets to attack -- and then take evasive action. The result is that recognition and identification have relatively less importance to the outcome of battle than our theoretical projections would lead us to expect. One cannot take the time to put a sophisticated target priority system into effect. Adding just a few seconds reaction time to the defense places the attacker in jeopardy.

Furthermore, attack team tactics will emerge as the most effective attack doctrine. These will permit shoot-and-scoot operations to be effective; and allow any attack under effective defensive fire to break off the firefight while his teammates press their attack.

The tactic that gives the defense the greatest freedom is the employment of camouflage and deception to allow the defender to select the moment, range, and conditions for him to initiate fire on the opposing attacking forces. Once opened, the camouflage and deception cover can be considered as compromised and no longer a factor in the firefight.

A-2.4 Formation and Unit Deployment Camouflage.

There is intelligence information at the recognition level to be gleaned from a formation of units that are individually revealed only at a detection level. That is, an array of blobs will in itself constitute a pattern of deployment such that in some instances the military function of the array is recognized. In this sense, the entire array constitutes a pattern that is resolved at the 10 to 12 line level with respect to the dimension of the array. The individual elements are resolved only at the limit of significant discernment.

Thus, even units covered with camouflage netting so that, as individuals, they appear only as a mound of background, may, by the pattern of distribution, lead to the recognition of the deployed unit.

Certainly a line of vehicles at uniform intervals along the side of a road would describe a military unit paused while on the march.

A-2.5 Camouflage and Target Reconnaissance.

Target reconnaissance is undertaken to obtain tactical intelligence on the deployment and strength of enemy forces. Camouflage is used where practical to conceal military units from discovery through the reconnaissance facilities of the aggressor. Camouflage is used to deny information to the opponent, by hiding and concealing the military forces from detection. Deception is used to give the opponent

false information. Camouflage and deception are used together as the situation allows. For example, camouflage nets may be used to conceal an entire unit, by denying detection of the individual elements, while several other alternate sites may be similarly camouflaged. While the reconnaissance may, for example, detect the presence of camouflage, the camouflage prevents the aggressor from determining which of the alternate sites contains the protected unit.

The aggressor seeks to identify the whole military unit, by type and by designation, and secondarily to identify the elements in order to determine the strength of the unit. He also may seek details of the unit deployment and defense in order to lay on a tactical attack by either area weapons (high-level bombs), artillery, or by aimed fire of projectiles or missiles. In the latter case, he is interested in estimating the capability of his attacking forces to acquire the individual elements in their firing sights.

A-3 VISUAL TARGET ACQUISITION, BACKGROUND AND CAMOUFLAGE

In this section is considered any acquisition means that presents to the observer a picture or image of the battlefield in a form that enables him to detect, recognize or identify a hostile military target.

The interactive variables then are a) the observed resolution over the dimensions of the target that is a function of the viewing technology; range, transmission of sight, obscurants, b) the observed nature of the background, and c) the built-in or added-on camouflage (and, of course, any deception devices or conditions). It is the purpose of this section to discuss a theoretical basis for estimation of the relationship among these factors.

The final answer, the bottom line, has to be determined with field experiments with mock-up or actual battlefield elements fielding in combat simulated conditions with camouflage or deception devices employed/not employed. Theoretical analysis is useful in the estimation of the gross parameters of design and in the range of their variation.

The goal of camouflage is to make the element protected indistinguishable from its associated background. The element becomes known to the observer, using his technical observation aids and his memory of past observations, by means of some significant difference or contrast between the observed characteristics of the background and those of the target element. In a general way, there are three categories of features that are involved in the observation in the image as presented to the observer:

- Form
- Color
- Intensity contrast

A camouflage pattern may, for example, successfully confuse the recognition of the form of the element observed, only to have that element reveal itself by some unique color associated with the object and the characteristics of the observation (e.g., IR photography, for example). Or the observed element may exhibit bright outline (glint) when illuminated with microwave radar.

The relationship between the appearance of a defended element and its background with respect to color, form and intensity is a constantly varying quantity. The ideal application of deception and/or camouflage is therefore also a varying quantity. Ideally, each tactical vehicle would be like a chameleon -- always changing its color, camouflage, and hue. Unfortunately, measures used to deceive and to camouflage are largely fixed -- or changed only through great effort. Hence, any one solution for deception and camouflage chosen is ideal for only one set of circumstances.

For example, a fighting vehicle in front of a wooded background some distance behind it can, in principle, be rendered almost undetectable by visual sighting when appropriately camouflaged -- say, on a bright clear day. However, if the atmosphere becomes hazy, a contrast will develop between the image of the vehicle and its background and the effectiveness of its camouflage measures may be totally lost. In a similar manner, a vehicle can be rendered essentially black when viewed with IR or radar imaging means. Against a background statistically "gray" and/or with mild radar reflectance, the blackened vehicle can stand out nakedly revealed.

Obviously, the design environment chosen should be coordinated with the tactical mission, doctrine and fighting terrain. It is a matter of tactical doctrine and can change from season to season, from urban to cross-country fighting.

The first principle is the selection of the fighting state for which acquisition protection is desired. Since most vehicles will spend a preponderance of their chronological time in a passive state, that condition, with the vehicle emplaced into its environmental background in a chosen manner, may be selected for the design environment condition.

On the other hand, a fighting vehicle may be more appropriately protected while it is in an inactive state -- since it will be largely in this state when it is manned and maintained in battle readiness.

Camouflage protection of a vehicle in an active state is largely useless.

In any case, it is important to keep in mind that any one solution of camouflage and deception will be appropriate for only one class of conditions. Target acquisition principles and theory are of no use in the choosing of the ambient environment for camouflage design. Whatever is chosen is a matter of tactical judgement and commitment and it will employ the desired tactical doctrine. Fighting doctrine and camouflage engineering should be made consistent.

A-4 MEASURES OF EFFECTIVENESS FOR CAMOUFLAGE

From a fundamental viewpoint, measures of effectiveness (MOE) are expressed as the product of attaining an ultimate goal multiplied by the value placed on that goal. In wartime, the polarization of all values comes from the dominating need to survive: for the nation to survive by winning the war. Thus, in principle, each MOE of an element should express the contribution of that element toward winning the war. Obviously, any evaluation of an MOE is a function of the particular situation of hostilities used as a context for its evaluation. For weapons systems designed during periods of non-belligerence, the situation of reference is the ***status quo ante bellum***. This concept, simple in expression, can be extraordinarily complex in analysis.

While there are occasions when a full scale analysis leading to MOE is justified and executed, the operation requires the efforts of scores of experts and the utilization of the most sophisticated computer supported data bases, models, simulations, and games. Costs running into millions of dollars per analysis are encountered. It is presumed that the elements (weapons, communications or surveillance systems) which are to be studied for applications of camouflage have been selected as part of the total weapons system array and that their use is already supported by suitable analysis.

In any analysis and estimate of MOE, the controlling determinant of the appropriateness of that analysis is the class of decision processes that are to be served by those estimates. An analysis that leads to non-ambiguous action and that is stable (no other decision indicated) against the addition of random selected considerations is appropriate for that decision. The MOE resulting is then meaningful and warranted for use with respect to that class of decision.

It is therefore appropriate that a MOE be based on a differential analysis selected so as to illuminate the effect of a change introduced into a situation. Such analysis may be created that can be simple in nature and minimal of cost. A MOE based on a differential analysis should not be blindly extrapolated to be used in some other problematic area since it has been reduced in scope and content around the sensitivities of the original problem area.

Furthermore, where interest is in the effectiveness of a simple change, such as the adding on of camouflage to a specific element, the full MOE analysis with and without camouflage would yield changes of comparative microscopic amount: the analyses would yield a small difference between very large numbers. The probable error of each large number will be orders of magnitude larger than such differences. So, besides being very expensive and time consuming, the answer obtained would be of dubious accuracy.

A differential analysis, on the other hand, features the direct effects associated with the choices (camouflage or no camouflage) and results in differences that are mathematically significant. Hence, it is possible to design a differential, marginal analysis, the result of which is significant with respect to the decisions faced: What is an admissible and effective camouflage? How does it affect tactics and doctrine? Compared to an uncamouflaged element, what is a measure of improvement--called here a measure of effectiveness (MOE)? It will be a MOE with respect to decisions faced, that is, for the decision class for which the analysis is warranted. It is not necessarily meaningful with respect to other decision classes.

A universal MOE is simple in concept, complex in estimation; a differential MOE is complex in concept, simple in estimation. Many times, the computation associated with an estimation of a differential MOE can be accomplished through the use of fairly simple algebraic formula.

The overriding test for admissability and adequacy of a differential MOE is the stability of the indicated decision with respect to either a) reasonable variation in input parameters and data and/or b) with respect to the addition of any (randomly) selected information. It doesn't matter how the numbers associated with the MOE change with the test a) and b) above; what matters is the stability of the indicated decision. For the purpose of that decision, the estimated MOE is sufficiently precise and accurate if the test for stability of decision passes the analysis.

The burden for the design of the MOE analysis then, rests with the developer, for the analysis usually has to be tailored uniquely for each application. There are no general purpose models or formulae. Only the methodology is common among the determinations. The price paid for simplicity in estimation is then this requirement that each application be special purpose and be unique for the class of weapons and decisions for which it is designed. The use of complex, sophisticated, detailed models, simulations or games is not only not justified, but can lead to error of conclusion.

A-5 FACTORS BEARING ON DIFFERENTIAL MEASURES OF EFFECTIVENESS OF CAMOUFLAGE

A-5.1 Intelligence Surveillance versus Target Acquisition.

Target detection and identification are processes that may be used for different purposes. The target arrays may be examined for intelligence purposes; to identify the nature of the combat force and its strength in order to estimate the battlefield situation. This is the function of target surveillance. The interest is not limited to the identification of the individual elements, but rather an identification of the force unit as a whole. The purpose of surveillance in some instances can be realized by a determination of the ground layout of a set of components observed at the detection level. That is, the array of militarily significant blobs may be sufficient to enable recognition of the type and, hence, purpose of the unit involved.

The utilization of camouflage for protection of the security of unit's identification from surveillance is thus a very different problem from that of camouflage utilized to deny or delay detection/identification of the individual elements for direct attack; i.e., for target acquisition.

Once identified, the presence of a military unit may be subject to attack by enemy attack weapons that utilize direct fire components to aim their armaments at individual elements of that unit (as distinct from area fire or bombs aimed at an area of map coordinates). As defense against such attacks, the individual units may be concerned with the use of camouflage to defeat, delay, or confuse the target acquisition of the elements for direct fire or the launching of armaments that are designed to detect and attack the defended elements.

The point is that camouflage and deception for counter-surveillance are distinct from camouflage and deception to defeat individual element target acquisition. These two functions shall therefore be treated separately in this discussion of measures of effectiveness.

A-6 TARGET ACQUISITION

A-6.1 Statement of Differential Measure of Effectiveness (DMOE).

The following is adopted as adequate and appropriate for this purpose of camouflage design and operational use.

The DMOE is conceived as the product of two functions. For some decision cases, only one of these may be needed:

DMOE = Product of Functional Lifetime of a [unit, element] multiplied by the Relative Functional Effectiveness of the operating condition at which the analysis is conducted.

In this definition, the Functional Lifetime = the expected duration of the time during which the [unit, element] is actively engaged in the function for which it is intended. For example, the reciprocal of the probability of non-survival yields the expected number of encounters; e.g., the lifetimes.

In this definition, Functional Time may be measured by the count of the number of episodes of active functioning (say engaging in a duel for survival with an opposing weapon) -- or functional time may be measured by the duration of chronological time that is advanced only when the [unit, element] is actively functioning.

Relative Functional Effectiveness (RFE) is that effectiveness relative to a base case under the operating conditions supposed by the situation under analysis. The expected number of enemy killed gives a measure of relative functional effectiveness. Hence, the ratio of enemy losses to friendly losses is a measure of the DMOE.

For example, assume a mobile air-defense multi-gun vehicle is detectable out to a range of 4000 m by an enemy target acquisition system. Then, the operating conditions imposed would be dominated by the enemy's capability for opening an engagement at 4000 m -- a distance wherein the guns of the AD vehicle have a low effectiveness as expressed by an exchange ratio of enemy killed to friendly loss (0.10 to 0.37). The same vehicle, now camouflaged to a degree that it cannot be detected beyond 1000 m by the same target acquisition system would be able to defer the opening of a duel until its engagement range was near 1000 m. At this distance, the expected exchange ratio of enemy lost per AD lost may be 3.7 to 5.1. In the first (uncamouflaged) instance, the expected lifetime of the AD would be multiplied by an RFE of 0.2; in the camouflaged case, by an RFE of 5.0 -- or a comparative effectiveness 25 times greater.

In summary, DMOE = FL x RFE

For special comparative situations, it may be sufficient to base conclusions (and base decisions) on the following simple measures (all at the 50% probability level):

a. Maximum range, attacker to defender, for target detection.
b. Maximum range, attacker to defender, for target recognition.
c. Maximum range, attacker to defender, for target identification.

It may be noted that once a target is detected, that its cover is essentially lost, for the attacker -- if he needs to recognize or identify, has a focus for his decreasing the range (after detection) to obtain the additional information needed. On the assumption of any activity whatever, he is motivated to press home his attack. For this reason, it is reasonable to conclude that the only important measure is (a) above:

Measure = maximum range from attacker to defender for target detection.

The differential measures, with and without camouflage, will give a comparative differential measure. For example, given that camouflage doubles the resolution needed to detection from 2 spatial lines per target dimension (without camouflage) to 4 lines resolution (with camouflage), the maximum range for detection without camouflage, Ro, will be replaced when camouflaged by Ro/2. Most current visual camouflage appears to be approximately 2 line camouflage at the extreme range of detection.

A-6.2 <u>State of Readiness</u>.

Three states of readiness of the defended element may be distinguished:

- Active
- Inactive
- Passive

An <u>active</u> element is defined to be in a state in which it is actively engaged in its combat function. If it has guns, it is shooting; if rockets, it is launching; if it is a communications element, it is communicating. That is, it is engaged in activity which in itself will attract the attention of the attacking enemy. (If its combat role is passive, as for example, an observation post, or a communications eavesdropping function, then its mission must be defined as essentially inactive; i.e., not emitting signals revealing its operational status.)

It is concluded that, for the most part, a vehicle or object in an active state has revealed itself -- blown its cover -- as far as passive camouflage is concerned. The presence of the defended element in a neighborhood of its location is open information -- like knowing a rabbit is in a thicket, even if you can't see him, he can be flushed out. Camouflage has little to contribute for elements in an active condition.

Elements in an <u>inactive</u> status are defined to be manned, with all systems activated to just short of an emitting level. That is, the power is on for all systems except for the emitting components. The prime power plant is operating. The element can shift to an active status by the simple act of throwing some switches (either manually or automatically). The objective of the use of camouflage is to permit the defender the delay of opening of active action to a moment of its own choosing.

In the case of an air defense vehicle (AD) utilizing guns as armament and facing an attack by opposing elements utilizing wire-guided (WG) missiles, it can be shown that the AD has a considerable advantage if he can defer the opening of a duel until the WG opponent (either an armed helicopter or an infantry fighting ground vehicle) is closer than 1000 meters. The WG armament is designed to have an advantage at the extreme ranges of its effectiveness (2000 m to 4000 m), where it is outside the effective range of gun/projectile firing arma nent. Figure A-2 shows the characteristic expected outcome of duels between an armed helicopter (AH) (firing a wire-guided missile) that pops up from behind a low lying defilade undulation in terrain, acquires the AD as a target and remains exposed while it guides its missile onto the defended target (the AD). The AD alerts from an inactive state and becomes active, acquires the AH on the radar, clears its guns and opens fire in short bursts. The figure shows the exchange ratios expected (on the average of many such engagements) as a function of range. At long ranges (2000 m to 4000 m), the AH has the advantage by a ratio of 10 to 1. At 2000 m, its about even; below 1000 m, the AD has a decided advantage up to 8 to 1.

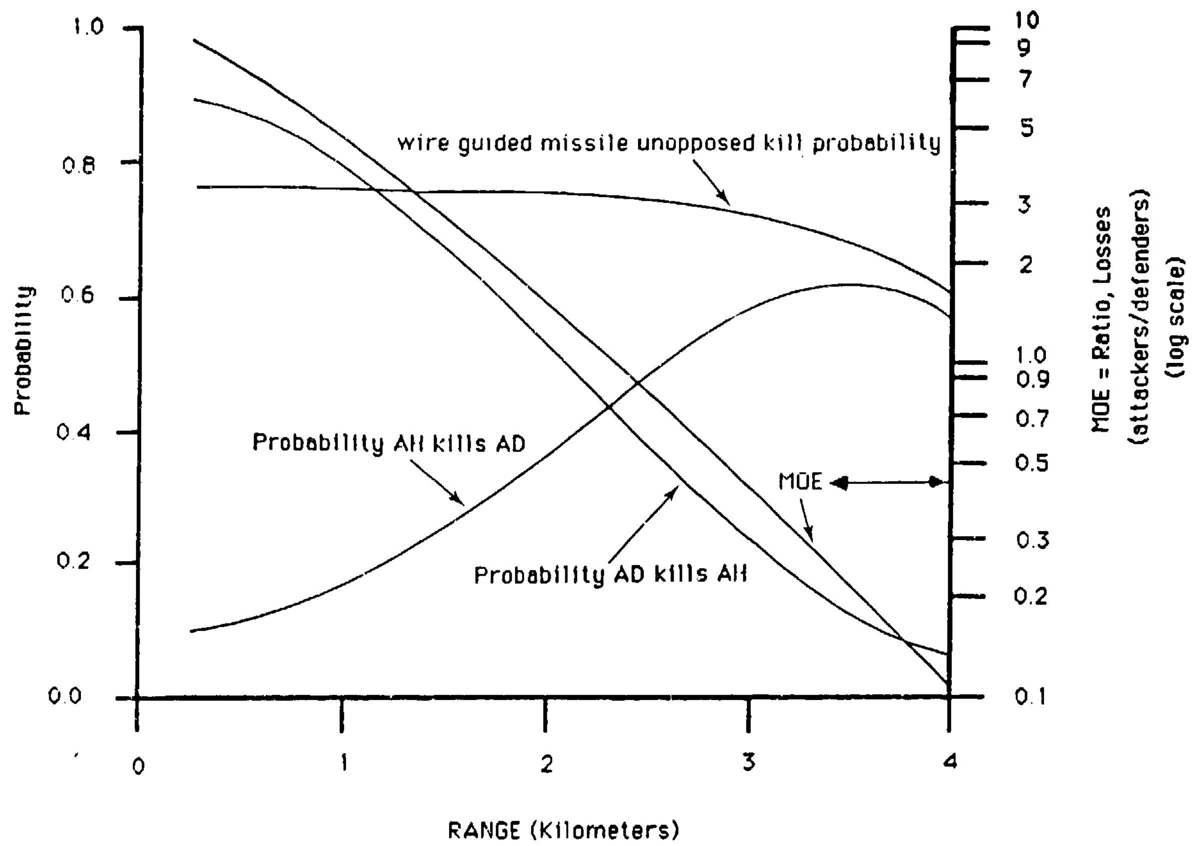


Figure A-2. Typical Curves for One-on-One Duel Between AH and AD.

The curve marked "MOE" in Figure A-2 is the ratio of the losses of the AH to that of the AD (in logarithm form). Since the reciprocal of the AD losses is its expected lifetime and the expected losses to the AH is its effectiveness (per encounter), this is the relative differential MOE as defined in this Appendix. To measure the effects of camouflage, compare the relative MOE for the ranges at which detection occurs, with and without camouflage.

Obviously, the tactic of the AD is to remain inactive until the range to an opponent has decreased to less than 1000 m. He cannot have this option available to him unless the maximum range for target acquisition (detection) of the AD by the AH is reduced to less than the desired 1000 m, and preferably below 500 m. There is here a tangible role for camouflage and deception.

Elements in a passive status are not in an alert status. If they have defense armaments, they require more time to bring their element to a state of battle readiness. On the other hand, while in a passive mode they presumably are not emitting heat/radiation that may be associated with motor-generator, petroleum fueled motors, or heat generated by function ready operating conditions. That is, they will not be generating the quantities of heat needed to maintain a battle-ready inactive condition. They trade, then, decreased vulnerability for detection because of heat generating equipment as an asset, for the liability associated with the increased time needed to achieve a battle-ready/active status. The requirements for camouflage are shifted away from the problems associated with IR detection. Since such elements will normally be equipped with heat dissipation deflection and IR shields for protection from IR acquisition when in the inactive mode, it remains the local commander's decision and initiative whether/when to permit his elements to go into a passive mode or else require them to maintain a battle ready inactive status. The basic design problems are subsumed under protection in the inactive mode.

APPENDIX B

CAMOUFLAGE CONCEPT AND SYSTEMS DESCRIPTIONS

This appendix contains a collection of data sheets describing current camouflage techniques, systems and materials which offer possibilities for employment to counter specific deficiencies. A technique is a procedure to produce camouflage: a camouflage system is a completed camouflage line item; and a camouflage material is something to be incorporated into a system through a technique. An example of a camouflage technique is the general procedure of using local, naturally occurring materials to produce camouflage; the technique description does not attempt an exhaustive classification of local materials, but does convey a broad understanding of the procedure. A camouflage system is a ready-to-use item, such as the lightweight screening system. A camouflage material needs to be manipulated by the user; e.g., cutting and forming radar absorbing material, RAM, in order to achieve the desired effect.

Table B-1 is an index of data sheets, listing number, title, and spectral region of effectiveness. The numbering system indicates whether the item is a technique (series 1000), a system (series 2000), or a camouflage material (series 3000).

Table B-1. Camouflage Data Sheet Index.

Data Sheet Number	Title	Effective Spectral Region*
1000	Reflectivity Reduction for Laser Susceptibility Control	UV, V, IR
1001	Controlling Radiant Energy from Objects	TIR
1002	Thermal Shielding	TIR
1003	Radar Countermeasure Design Configurations	R
1004	Control of Surface Scattering (Texturing)	UV, V, NIR
1005	Control of Exhaust Gas Temperatures by Mixing with Heat Absorbing Liquids or Gases	TIR
1006	Camouflage Using Local Materials	UV, V, NIR
1007	Standardized Camouflage Pattern Painting (SCAPP)	UV, NIR, TIR
1008	Camouflage Disrupters	UV, V, NIR, TIR
1009	Disguise Techniques for Rolling Stock	V
1010	Decoys	ALL
2000	Camouflage Screens (Nets)	UV, V, NIR, R
2001	Camouflage Foliage Brackets and Spring Clips	V, NIR, TIR
2002	Camouflaged Covers for Highly Reflective Surfaces	UV, V, NIR
2003	Camouflaged Covers for Components that Cannot be Painted with SCAPP	UV, V, NIR
3000	Radar Absorbing Material-Flat Plate, Resonant	R
3001	Radar Absorbing Material-Flat Plate, Broad-band, Graded	R
3002	Radar Absorbing Material-Ferrite	R
3003	Radar Absorbing Material-Low Density	R
3004	Radar Absorbing Material-Circuit Analog	R
3005	Radar Absorbing Material-Geometric Transition	R
3006	Chemical Agent Resistant Coatings (CARC) for SCAPP	UV, V, NIR
3007	Paint, Camouflage, Removable, for SCAPP	UV, V, NIR
3008	Paint, Heat Resistant, for SCAPP	V, NIR
3009	Camouflage Cloth	UV, V, NIR, TIR
3010	Paint, Special Purpose	V, NIR, R
3011	Low Reflective Coating for Aircraft	NIR
3012	SCAPP Application to Fabric Components of Tactical Equipment	V

* UV = Ultraviolet
V = Visual
IR = Infrared
TIR = Thermal Infrared
NIR = Near Infrared
R = Radar

TITLE: REFLECTIVITY REDUCTION FOR LASER SUSCEPTIBILITY CONTROL	DATA SHEET: 1000 PAGE 1 OF 1

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

To reduce the effectiveness of laser designators and rangers against materiel.

POTENTIAL APPLICATION:

For use with tanks, armored personnel carriers, etc.

DESCRIPTION:

It is possible to apply coatings to materiel which will substantially reduce the optical return received by laser systems such as designators and rangers; the threat cannot be eliminated but it can be reduced.

Changing the diffuse reflectivity from 10% to 2% is probably achievable and would reduce the effective range of an attacking system by approximately a factor of two. Because of the high cost of this technique, it would only be used on expensive systems.

EXPERIENCE:

The specially treated surface is prone to the accumulation of dirt or moisture which negates the effect.

TITLE: CONTROLLING RADIANT ENERGY FROM OBJECTS	DATA SHEET: 1001
	PAGE 1 OF 1

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

To deny detection by thermal infrared sensors by reducing an item's apparent temperature contrast with its background.

POTENTIAL APPLICATION:

To items or parts that elevate in temperature during operation and thereby create a contrast with their background.

DESCRIPTION:

The intensity of thermal radiation is a function of surface temperature and the emissivity of the surface. It is possible to control this radiant energy by applying coatings which have different emissivities in patterns similar to normal background. This is the IR analog to the visual camouflage painted patterns. A second technique for controlling emission is to apply a coating with a variable emissivity, i.e., one which, as the surface temperature increases, the emissivity of the coating decreases, thus appearing to be cooler than it is.

EXPERIENCE:

The pattern emissivity technique has been shown to be as effective as visual camouflage pattern painting, which is applied to all Army combat vehicles. The variable emissivity coating has not achieved its goal, but progress has been made and work continues.

TITLE: THERMAL SHIELDING	DATA SHEET: 1002
	PAGE 1 OF 2

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

To minimize detection of military objects by "thermal" sensors including terminal homing.

POTENTIAL APPLICATION:

Primarily to hot target parts which are external and not readily treatable by other means. Examples include engine exhausts, high temperature parts resulting from weapon firing, and high friction parts.

DESCRIPTION:

Remote sensing of thermal variations between targets and their backgrounds utilizes electromagnetic radiation, primarily in the spectral window regions of 3- to 5-micron and 8- to 14-micron wavelength. All surfaces above absolute zero temperature emit infrared radiation characteristic of the surfaces' temperature and emissivity. If the radiation emitted by the surface is sufficiently different from its surroundings, an image of that surface can be produced by electronic thermographic instruments which record the radiation in the direction of the sensor. Such instruments have detected temperature differences of as little as 0.2°C. Blocking this radiation by interposing an opaque shield between the surface emitting the radiation and the sensor prevents the sensor from recording the surface radiation. The shield, however, is subject to observation in precisely the same fashion and over a period of time, depending on its physical nature, it will absorb the radiation from the surface to be hidden, increase in temperature, and in turn, be detectable. This can be minimized by:

(a) using a stand-off distance between the shield and the object surface;

(b) using an inner shield surface of low emissivity to minimize energy transfer from the object surface;

(c) making the shield of a low thermal conductivity material; and

(d) configuring the shield outer surface to have a greater area than the inner surface, have a low emissivity in the 3- to 5-micron and 8- to 14-micron regions (while retaining good optical color and texture) and giving the shield a shape corresponding to the backgrounds in which the target is expected to function.

Shields will tend to be thin and low in mass which will quickly absorb or release energy to seek equilibrium with the air. Since the air is generally at a different temperature than the ground, or other background, the shields themselves are detectable and, therefore, must assume the nature of a disguise to reduce object perceptibility. An ideal shield would utilize a further means of temperature control through junction electronics (or other means) to vary the temperature of the shield and its emitted radiation to simulate the background using the feedback from a local monitor (sensor).

The use of forced air or other gas coolant between the object surface and the shield aids convective cooling of the shield.

For an integrated shield to be effective across the entire EM spectrum, it would require incorporating radar shielding techniques (see Radar Screening and RAM) and configurations, colors, and textures designed to defeat optical and near IR imaging sensors.

EXPERIENCE:

Thermal shielding has been successfully applied to aircraft engines to reduce the threat from thermal homing missiles and in the form of thermal modulators in an experimental camouflage system for a 45 KW diesel generator, and in the form of double screens for troop applied camouflage over static equipment and positions.

OTHER CONSIDERATIONS:

Shielding of very hot or otherwise untreatable portions of targets is the best application of this technique. Application to the whole target is less successful and interferes with access to the equipment.

Whole object camouflage by individual shields has low success probability on targets which tend to exceed background temperatures all over.

Selective applied shielding can be very effective in blocking highly detectable radiation to a sensor; especially to defeat a homing device using the 3-5 and 8-14 micron windows.

TITLE: RADAR COUNTERMEASURE DESIGN CONFIGURATIONS	DATA SHEET: 1003
	PAGE 1 OF 6

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

To provide guidance to equipment developers on configurations to be avoided and those to use for maximum camouflage effectiveness in concealing from radar, by reducing the radar cross section of the equipment.

POTENTIAL APPLICATION:

Military hardware items/systems.

DESCRIPTION:

Design configurations to be avoided include the following:

1. Rounded geometries which always provide a direct (90°) incident face at any illumination angle.

2. Normal incident faces between the +20° and +40° elevation angles associated with airborne platforms.
   rapment cavities and major acute angle configurations. Cavities formed by structural configuration, large viewing ports, searchlights, etc., form critical energy "getters" which yield a concentrated return.

Design configurations to be incorporated where practical include the following:

1. The use of non-metallics and non-water-absorbing materials for protruding structures.

2. Shape, reshape, or cover critical structures or cavities with wire screening or other radar-opaque materials, so that they meet the above geometric requirements.

3. Consider the use of radar-attenuating coatings for otherwise inflexible design configurations.

EXPERIENCE:

These design "do's" and "don'ts" result from the examination of many equipment types tested extensively in both ground and air field tests by all armed services.

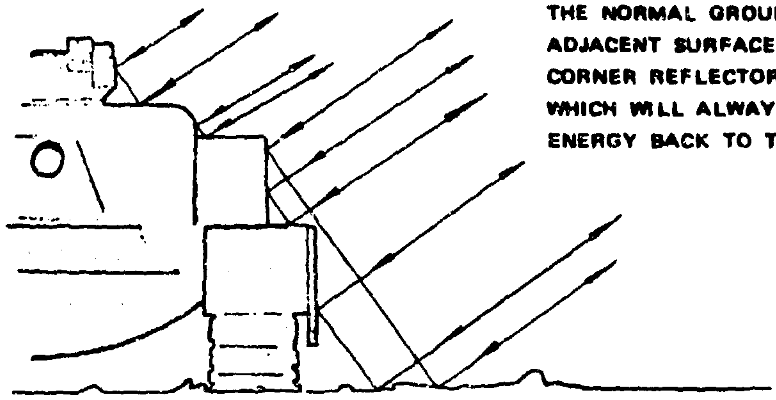
OTHER CONSIDERATIONS:

The basis for these tips is the examination of the detailed structural configurations which, collectively, produce a weapon system's radar cross section (RCS).

These tips are primarily effective for equipment in a static mode. Moving target indicator (MTI) radar effectiveness will only be marginally improved the these techniques.

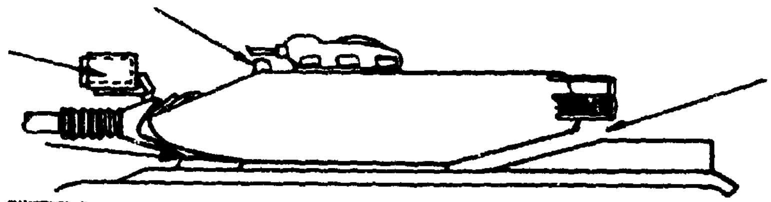
TITLE: RADAR COUNTERMEASURE DESIGN CONFIGURATIONS	DATA SHEET: 1003
	PAGE 3 OF 6

AVOID ALL 90° (CORNER REFLECTOR) GEOMETRIES:

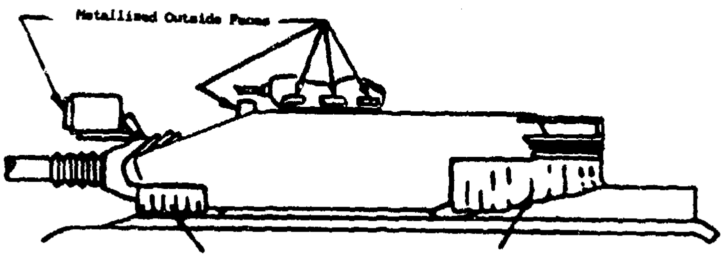


ANY SURFACE ORIENTED 90° FROM THE NORMAL GROUND PLANE OR AN ADJACENT SURFACE CREATES A CORNER REFLECTOR SITUATION WHICH WILL ALWAYS REFLECT ENERGY BACK TO THE THREAT RADAR

Avoid energy entrapment cavities or major acute angle configurations:



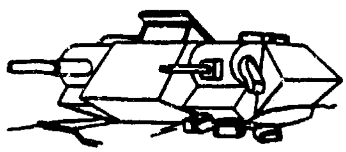
CAVITIES FORMED BY STRUCTURAL CONFIGURATIONS, LARGE VIEW PORTS, SEARCHLIGHTS, ETC. FORM CRITICAL ENERGY "GETTERS" WHICH YIELD A CONCENTRATED RETURN. WHERE IT IS FUNCTIONALLY IMPOSSIBLE TO MINIMIZE THEIR EXTENT, TRY TO RENDER THEM RADAR-OPAQUE, AS FOLLOWS:



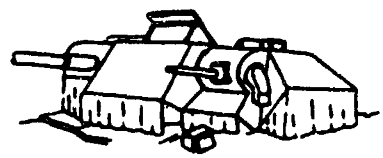
Attach Curtains of Metallized Cloth or Camouflage Material

TITLE: RADAR COUNTERMEASURE DESIGN CONFIGURATIONS	DATA SHEET: 1003
	PAGE 4 OF 6

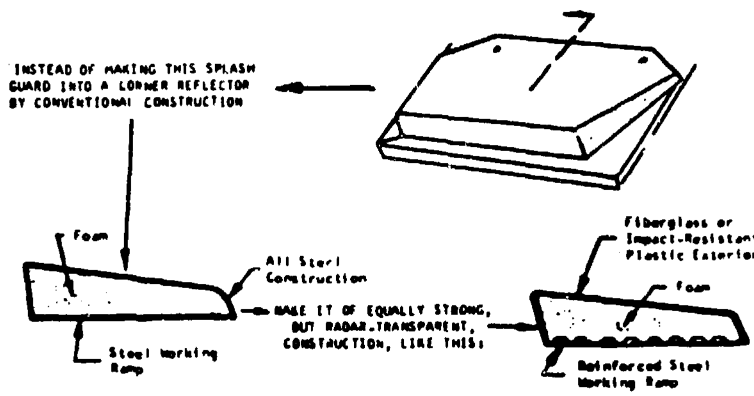
Avoid energy entrapment cavities or major acute angle configurations:



TYPICALLY, BY HANGING METALLIZED CURTAINS OR RADAR-SCATTERING CAMOUFLAGE AROUND THE TURRET, BALLISTICS OR OPERATIONAL PERFORMANCE WOULD NOT BE AFFECTED, SIMILARLY, "METALLIZING" THE NECESSARY VIEWPORTS WITH WIRE SCREENING OR THIN FILMS WOULD NOT IMPARE INTERNAL VISUAL PROPERTIES.

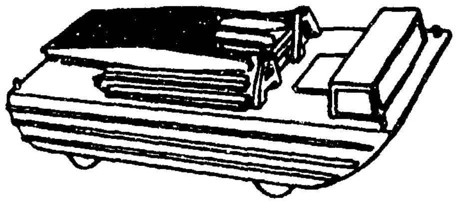


Where practical, use nonmetals for necessary protruding structures:

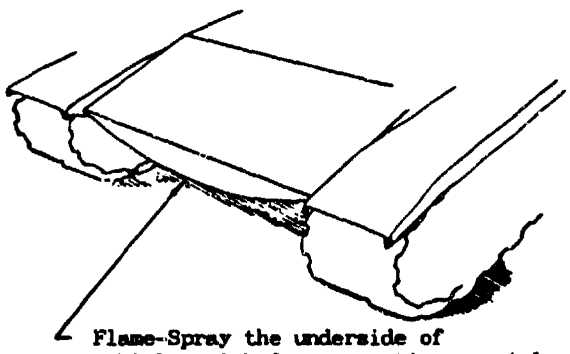


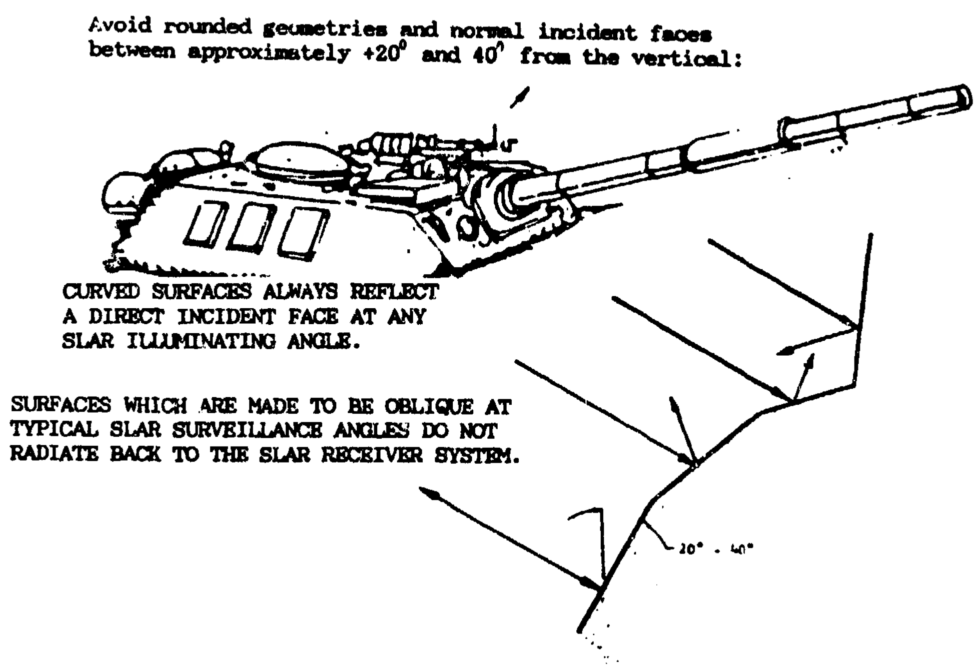
SIMILARILY, CONSIDER MAKING HAND-HOLDS, TIE-DOWNS, ETC. OF RADAR-TRANSPARENT FIBERGLASS OR PLASTIC CONSTRUCTION.

Where practical, reshape or cover critical areas with wire screening or other radar-opaque materials:



Consider the use of radar-attenuating coatings for otherwise inflexible design configurations:




Avoid rounded geometries and normal incident faces between approximately +20° and 40° from the vertical:
CURVED SURFACES ALWAYS REFLECT A DIRECT INCIDENT FACE AT ANY SLAR ILLUMINATING ANGLE.
SURFACES WHICH ARE MADE TO BE OBLIQUE AT TYPICAL SLAR SURVEILLANCE ANGLES DO NOT RADIATE BACK TO THE SLAR RECEIVER SYSTEM.
20° - 40°

TITLE: CONTROL OF SURFACE SCATTERING (TEXTURING)	DATA SHEET: 1004
	PAGE 1 OF 2

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

To eliminate shine by controlling the specular reflection from surfaces.

POTENTIAL APPLICATION:

All exterior surfaces subject to observation.

DESCRIPTION:

Shiny surfaces exhibit specular reflection because nearly all the reflected energy is confined to a viewing angle dependent on the illumination angle. Matte surfaces, because they are textured, eliminate this "spike" of reflected energy by distributing it in a hemispherical pattern. Figure 1 depicts the relationship between illuminating angle and the relative angular intensity of reflected energy, for a shiny surface and for a matte surface, as measured by a goniophotometer.

Windshields, cooking pans and shiny metallic surfaces of vehicles are examples of surfaces that exhibit a high degree of specular reflection. This specular reflection is commonly detectable from long range and should be minimized by: building texture in a surface; permanently adding texture, e.g., by applying matte coatings; or by temporarily adding texture, e.g., covering the surface with camouflage cloth.

A smooth hot surface will emit thermal infrared radiation primarily in the direction perpendicular to the surface. Texturing the surface will hemispherically distribute the emissions; therefore, to a thermal sensor positioned normal to the flat surface, the surface will appear cooler if it is textured.

EXPERIENCE:

Most camouflage paints are formulated to yield a matte surface. Camouflage paints are currently applied to mobility equipment during manufacture.

Camouflage fabrics, e.g., those currently specified for cargo and vehicle covers, are produced with matte surfaces.

TITLE: CONTROL OF SURFACE SCATTERING (TEXTURING)	DATA SHEET: 1004

The camouflage cloth used in camouflage screen (LSS) fabrication possesses a matte surface.

OTHER CONSIDERATIONS:

Textured surfaces are prone to abrasion and collection of dirt and debris; maintenance procedures should include provisions for restoring textured surfaces.

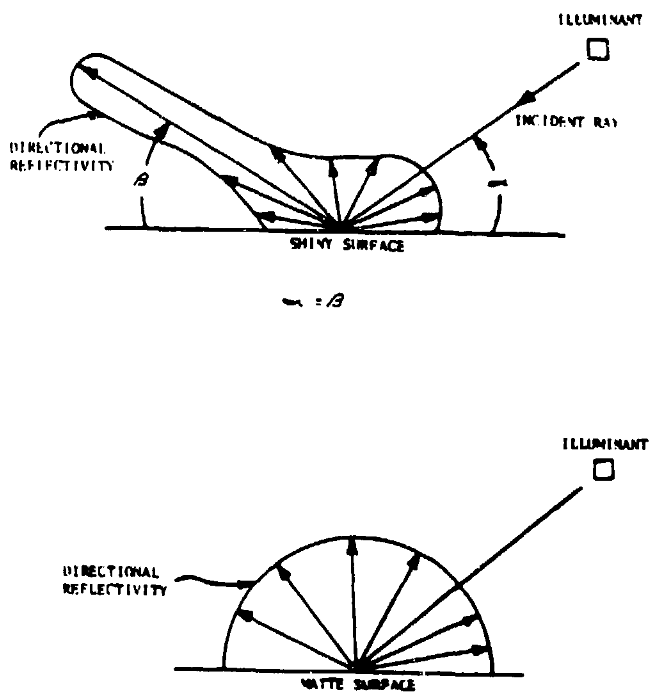


Figure 1. Relationship Between Illuminating Angle and Relative Angular Intensity.

TITLE: CONTROL OF EXHAUST GAS TEMPERATURES BY MIXING WITH HEAT ABSORBING LIQUIDS OR GASES	DATA SHEET: 1005
	PAGE 1 OF 2

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

To reduce thermal signatures and hot points in order to defeat thermal infrared sensors.

POTENTIAL APPLICATION:

All internal combustion engines.

DESCRIPTION:

Combustion products from internal combustion engines are normally exhausted through one or two pipes after passing through a sound reducer (muffler). These pipes are generally located to minimize crew exposure to dangerous gases and, in military vehicles, elevated to permit maximum fording capability. These pipes become very hot and are excellent homing points for thermal sensors.

In some cases, the exhausts are located inside a grill (for physical protection) resulting in a large hot area. Mixing cold outside are and injecting volatile liquids to the exhaust close to the engine can cool the exhaust gases and thus reduce heating of the metal pipes, grills, etc., which would otherwise become intense radiators of infrared energy.

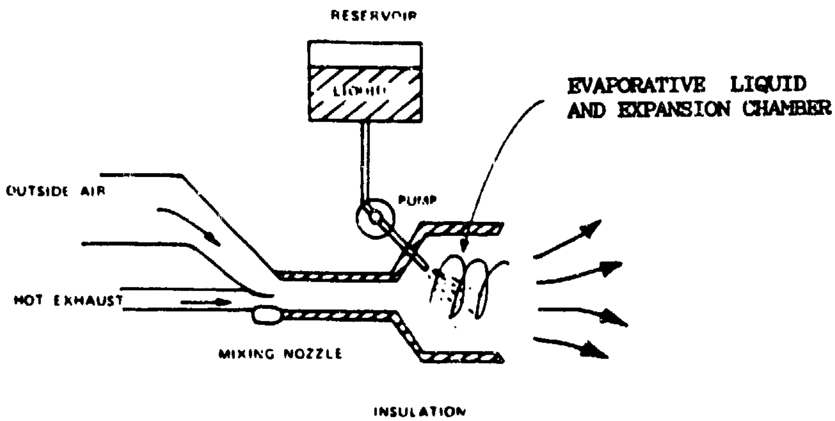
EXPERIENCE:

Main battle tanks and Army helicopters have been modified to draw in ambient air and mix it with exhaust gases before being exhausted through insulated ports. A reduction in detectability range is thus achieved against the thermal sensors.

OTHER CONSIDERATIONS:

The use of air as a coolant, especially moist air, is effective and requires little additional energy expenditure by the power source of the item. The use of fluids injected into the exhaust, however, requires storage space, and resupply restricts its use to critical moments.

TITLE: CONTROL OF EXHAUST GAS TEMPERATURES BY MIXING WITH HEAT ABSORBING LIQUIDS	DATA SHEET: 1005
	PAGE 2 OF 2



CONTROL OF EXHAUST TEMPERATURES THROUGH MIXING WITH HEAT ABSORBING GASES OR FLUIDS

TITLE: CAMOUFLAGE USING LOCAL MATERIALS	DATA SHEET: 1006
	PAGE 1 OF 2

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

Local materials can be utilized to blend an item with its natural surroundings.

POTENTIAL APPLICATION:

Many items of military equipment can be camouflaged with natural materials, either as the sole camouflage technique or to supplement built-in, add-on or field-applied synthetic camouflage.

DESCRIPTION:

Many items of military equipment have no built-in camouflage or, in some cases, only forest green coloration. Natural vegetation, dirt, sand or rocks can be placed on or around these items for camouflage. Pattern painted equipment can also benefit from this additional camouflage because pattern painting does not break up regular geometric outlines or characteristic signatures (gun barrels, antennas, windows, etc.); correct placement of local materials can blend these cues into the natural surrounding.

Even equipment that is camouflaged with the lightweight screening system (LSS) (see Data Sheet 2000) or synthetic disrupters can sometimes benefit from selective placement of local materials. Large objects which require two or more LSS modules are especially vulnerable to detection because of their size.

Listed below are some additional factors that should be considered when using local, naturally-occurring materials for camouflage:

- Cut vegetation will wilt and lose its natural shape and color in a matter of a few hours to a few days; it therefore needs to be periodically replaced in order to maintain effectiveness.
- Soil will also wash off walls and surfaces when it rains and it also needs to be periodically replenished.
- Foliage brackets (see Data Sheet 2001) need to be designed into equipment, or provisions made for adding to existing equipment, to facilitate the attachment of natural vegetation.

- Good concealment is possible if the equipment can be located within existing foliage, i.e., eliminating the need to use cut vegetation. Planting natural vegetation around a permanent structure also provides good camouflage.

EXPERIENCE:

Using cut vegetation for blending purposes is one of the oldest forms of camouflage.

More recently, special clips have been designed for holding natural materials on 120 mm, 90 mm, and 76 mm gun barrels of armored vehicles (see Data Sheet 2001).

OTHER CONSIDERATIONS:

Shiny objects on equipment, such as windows and lenses, are not easily hidden by local materials. An opaque material, such as sheets of unincised camouflage cloth (see Data Sheet 3009), should be placed over these cues.

TITLE: STANDARDIZED CAMOUFLAGE PATTERN PAINTING (SCAPP)	DATA SHEET: 1007
	PAGE 1 OF 3

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

To provide a basic camouflage system upon which additional camouflage measures will be built. SCAPP represents a "built-in" system that will enhance the survivability of tactical materiel by reducing its contrast with natural surroundings and suppressing the features that would cause it to be easily identified. The case of Chemical Agent Resistant Coating (CARC) will also allow SCAPP equipment to be decontaminated without removing the camouflage paint.

POTENTIAL APPLICATION:

AR 750-1 requires all tactical materiel to be painted with SCAPP using CARC. SCAPP will also be applied to soft components such as cargo covers, doors and cab tops where applicable (see Data Sheet 3012).

DESCRIPTION:

All tactical equipment possesses characteristic shapes and shadows that contrast with natural surroundings, causing it to be conspicuous and recognizable. Camouflage pattern painting has been employed by armies to reduce this contrast with nature and decrease the probability that a hostile observer will detect and recognize the army's equipment.

Since 1974, the U.S. Army has been camouflage pattern painting its tactical equipment. The first pattern scheme adopted utilized four colors and could be converted for different seasons or geographic conditions by changing one or two of the four colors. The four color patterns were applied by troops using a family of alkyd-enamel camouflage paints.

In 1983, the armies of the U.S. and Germany jointly adopted a new camouflage scheme called Standardized Camouflage Pattern Painting (SCAPP). By standardizing the paint systems of their armies, the U.S. and Germany would become a more effective fighting force in Central Europe by minimizing the visible differences of their combat hardware. Enemy forces would have a difficult time discriminating between SCAPP equipment of the U.S. and Germany and would have a more difficult time discerning Order of Battle.

TITLE: STANDARDIZED CAMOUFLAGE PATTERN PAINTING (SCAPP)	DATA SHEET: 1007
	PAGE 2 OF 3

SCAPP is a very effective camouflage scheme at long distances. The large color portions of SCAPP are placed to distort interior shadows, cut off corners and break up straight lines. Distinctive surface features are suppressed with black paint in order to make an item less recognizable. Lusterless colors reduce the contrast of man-made hardware with a natural environment.

SCAPP is a world-wide, year-round camouflage scheme. The pattern is designed to distort the silhouette of an item. Three contrasting colors are used to provide a disruptive visual effect at long distances (2000-3000 m) and short ranges (0-800 m). The Standard (Woodland) scheme should be applied to all newly manufactured equipment using CARC. (The Standard colors are Green 383 (41%), Black (44%) and Brown 383 (15%).) Variations of this scheme will be rare since conversions for desert or winter conditions will be accomplished by troops using temporary camouflage paint (see Data Sheet 3007). Only equipment dedicated to certain geographic regions (such as SWAPDOP or Arctic Fuels Dispensing Equipment) will be painted using permanent colors other than Standard.

SCAPP designs are prepared by countersurveillance experts at Belvoir RD&E Center, Ft. Belvoir, VA, using accurate, scaled drawings of the equipment. Once the SCAPP design is completed, the SCAPP drawings become Government furnished equipment to manufacturers. The production contract (or purchase description) should specify manufacturers application of SCAPP using CARC. Belvoir can provide assistance to Materiel Developers in preparing the necessary contract documents.

EXPERIENCE:

Since 1983, over 400 individual SCAPP designs have been prepared by Belvoir. Figure 1 shows the SCAPP for the 1-1/4 ton weapons carrier. A system for inspection of the applied SCAPP has been prepared to support contract painting. On site consultation has frequently been provided by Belvoir engineers to assist OEMS painting and quality assurance efforts. Techniques for applying SCAPP to fabrics have been identified. Temporary paints are used to convert SCAPP from one geographic or climatic condition to another (see Color Codes Chart in Figure 1). The application of SCAPP to newly manufactured equipment is the most efficient means for the U.S. Army to obtain camouflaged equipment. Data items have been approved for use in production contracts. All major systems now receive SCAPP prior to delivery to the U.S. Army. Troops are furnished battle-ready equipment and are required to perform touch-up painting only. CARC provides a coating system that is more durable, longer lasting and easily decontaminated.

TITLE: STANDARDIZED CAMOUFLAGE PATTERN PAINTING (SCAPP)	DATA SHEET: 1007
	PAGE 3 OF 3

COLOR CODES			
NO.	STANDARD	DESERT	WINTER/SNOW
1	BLACK	TAN 686	BLACK
2	GREEN 383	TAN 686	WHITE
3	BROWN 383	TAN 686	BROWN 383

	SIZE	FSCM	DWG NO
DATE 24 Jul 86	D	97403	13226E7108

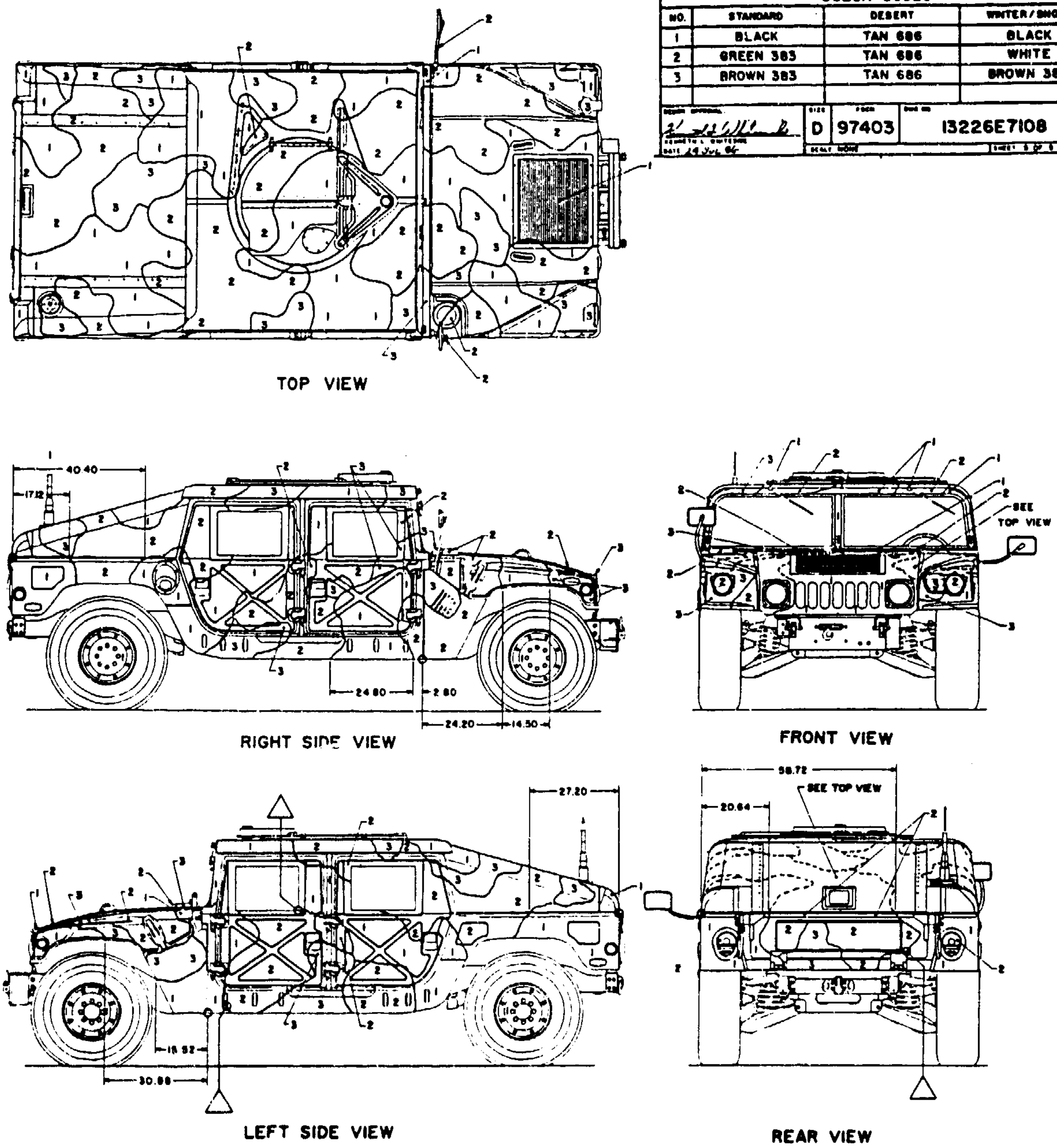


Figure 1. Pattern Painting Design for the 1-1/4 Ton Weapons Carrier.

TITLE: SHAPE DISRUPTERS FOR CAMOUFLAGE	DATA SHEET: 1008
	PAGE 1 OF 2

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

To permit quick reaction camouflage of equipment and sites under more circumstances than are possible or practical with screens or other existing means; especially in a fire fight requiring frequent movement.

POTENTIAL APPLICATION:

Shape disrupters can be used with most items of TOE tactical equipment, especially armor and air defense units.

DESCRIPTION:

Shape disrupters are typically expandable and retractable devices capable of attachment to select locations on military equipment or are capable of free-standing use. One common type of disrupter consists of a center support pole and radial ribs which support the garnishing material.

Shape disrupters are deployed on, and serve to conceal, equipment corners and other characteristic geometrical contours, e.g., dish antennas, wheels, wheel wells, gun barrels, and spotlight lenses. More than one disrupter is generally required to achieve the desired camouflage effect. Since complete hiding or blending of the equipment is not usually practical with disrupters, planning must go into their location, shape, size and orientation. This planning must include considerations for the probable nature of the threat (unfriendly observation), e.g., low level or high level aerial observation or ground observation.

EXPERIENCE:

In the past, significant effort has gone into the development of disrupters for equipment, for example, the HAWK missile system.

TITLE: SHAPE DISRUPTERS FOR CAMOUFLAGE	DATA SHEET: 1008
	PAGE 2 OF 2

OTHER CONSIDERATIONS:

Disrupter design should include provisions for:

1. Folding into small packages which have protective covers and which will permit negotiation of terrain in a manner comparable to the item without disrupters.

2. Several sizes and configurations to meet the needs of geometrics of various equipment.

3. Simple replacement, in the field, of the garnish by the equipment operator; this allows replacement of worn or damaged material and also permits changes dictated by geographical or climatic conditions.

TITLE: DISGUISE TECHNIQUES FOR ROLLING STOCK	DATA SHEET: 1009
	PAGE 1 OF 2

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

This Disguise will protect rolling stock transporting high-value combat equipment and material such as fuel, tanks and ammunition. While in transit the rolling stock and its cargo is easily recognized as representing a high value and extremely vulnerable target. A Disguise kit can hide the cargo from hostile observers and cause them to believe the item is something other than a prime target.

POTENTIAL APPLICATION:

All rolling stock that carries easily recognized high value cargo, such as M970 fuel tankers, M747 tank transporters and flat-bed rail cars. This concept can be applied to any vehicles or equipment that are easily recognized or conspicuous in appearance. For example, in WWII, a Sherman tank was disguised to look like a standard cargo truck, a target of much lower value.

DESCRIPTION:

The Disguise Cover is made of a fabric such as vinyl coated cloth or a woven duck cloth that is installed over a box-shaped framework.

The Disguise Kit consists of two principle components: 1) the fabric cover and, 2) the support frame. The fabric cover can be a vinyl coated cloth or woven cloth that is printed or coated with a camouflage pattern or some markings such as doors and access panels. These exterior markings cause an observer to conclude that the object is something completely different from what it actually is, and prevents recognition of the actual cargo.

The Support Frame should be designed to be installed quickly by two crew members. It should be lightweight but strong enough to handle the forces generated by wind when the vehicle is underway. Both the Support Frame and Cover should be easily stored on board the vehicle when not in use.

The best design will be a simple and easily installed Cover over easily installed and recovered bows. Clearance must be provided for any likely cargo such as tanks or ammunition. Mounting brackets for the frame should be permanently fixed to the transporter to expedite the installa-

tion or the frame. The Cover should have either a camouflage pattern or other visible markings printed on its exterior surface to provide the desired illusion.

EXPERIENCE:

Transportation personnel have expressed their desire to have such a kit developed for tank transporters (M747 semi-trailer). US Army Europe has requested a similar kit be developed for semi-trailer-fuel tankers (see Figure 1). Disguise and deception have been effective means of protecting assets that are particularly recognizable during transport. Camouflage for such moving objects provides only minimal protection, since motion, noise and other signatures prevail during transport. Deception is the best method of enhancing the survivability of rolling stock.

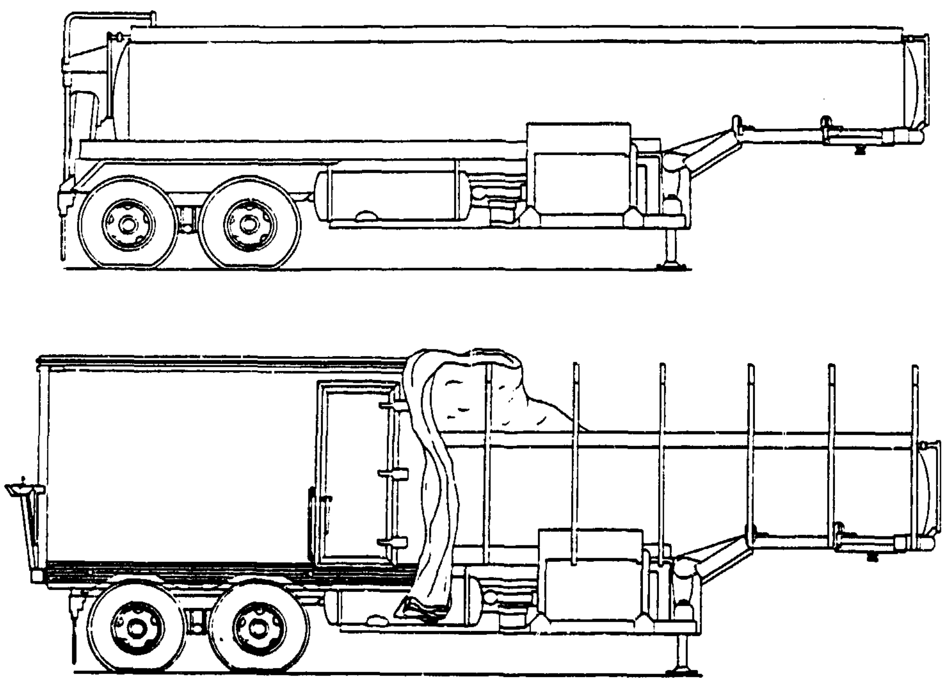


Figure 1. Disguise for Gasoline Truck.

TITLE: DECOYS	DATA SHEET: 1010
	PAGE 1 OF 2

Camouflage Technique [X] Camouflage System [ ] Camouflage Material [ ]

PURPOSE:

Decoys deceive enemy observers by creating emissions, cues, and signals, which simulate vehicles, tanks, guns, or other items or equipment.

POTENTIAL APPLICATION:

Many items of military equipment are candidates for simulation, using decoys, where the level of concealment necessary for survivability cannot be assured. Particular applications will usually involve use of decoys to draw attention or enemy fire away from nearby "real" targets and cause the enemy to waste firepower. Equipment decoys used in the future will normally require a full scale of simulation including electronic, IR, Radar, etc.

DESCRIPTION:

One way of describing decoys is by their fidelity, the degree of detail to which the real item and its properties are copied. The fidelity required must be defined early in the design and development. This definition will come from assessing the sensor threats and the ranges at which those sensor threats must be deceived.

Shape and visual appearance are among the first items considered in the design of a decoy. The overall geometrical form can easily be copied to a high degree of fidelity; large signature cues, e.g., gun barrels or radar transmitter receiver dishes are considered part of this intrinsic form. Lenses, small antennas, hubcaps, bun sights, and other small cues may be omitted if the fidelity requirements are not great. Standard coloration of the original item, like original paint, is usually readily available and nearly always should be used with the decoy.

When the deception of sensor threats other than visual observation is also part of the fidelity requirements, then equal design care should be given to deceive threats operating on these principles.

- Photography (including color and infrared)

- Infrared energy (thermal, night vision devices, etc.)

- Millimeter-Wave
- Microwaves
- Acoustic, Seismic, magnetic
- Chemical

Based on the overall importance to the Army (and relative cost of the item), development and use of an individual decoy (carried on board and used by the crew as appropriate) should be considered as part of the equipment to be tactically employed.

EXPERIENCE:

Most decoy effort in and since WWII was concerned with providing a tactical cover and deception capability. One specific decoy not now in use was the development and fielding of a decoy of high fidelity in the visual and radar regions. It was used by the artillery units employing the archetype and served to protect the real weapon.

TITLE: CAMOUFLAGE SCREENS (NETS)	DATA SHEET: 2000
	PAGE 1 OF 7

Camouflage Technique ☐ Camouflage System ☒ Camouflage Material ☐

PURPOSE

To conceal military equipment, installations, and activities from observation by sensor systems utilizing reflected energy from the target.

POTENTIAL APPLICATION:

To most combat equipment, installations, and small local activities which are to remain in a static position for relatively short times and to far more permanent installations over a longer time where the objective is primarily to defeat effective identification of the target and/or reduce the effectiveness of attack thereon.

DESCRIPTION:

Camouflage screens (nets) are the principle field means employed by most armies to conceal combat positions and equipment. In their modern form, they date from WWI where a countermeasure was needed to defeat the aerial camera. They are also almost universally misunderstood and, therefore, improperly used.

In order to obtain the surface texture scattering of incident illumination and permit as much free air and water vapor passage with as little bulk and weight as possible, screens made for employment in foliated terrains have significant openness in their garnishing. (Garnish is a term used to describe a colored and textured material applied to a net support of cord or wire.) Viewing such a screen against a lighted background (sky) will demonstrate that there is see-through (except at radar frequencies when the screen has been provided with anti-radar capability). Camouflage screens conceal not so much by hiding the target,as by casting a shadow within which the target is not discernable, i.e. , below the contrast threshold of the sensor.

Since the target would be perceptible without the screens because of the target's characteristic shadow and reflectance tones, the screen must overcome these if the target is to be concealed; otherwise, the outline or form of the target would be recognizable. It is, therefore, essential that the background and the target under the screen be matched as nearly alike in reflectance as possible or the form will still be perceptible through the screen.

An illustration of this principle familiar to nearly everyone is a thin window curtain (not a drape). On the inside during the day, objects outside can be viewed fairly easily through the curtains; conversely, from the outside, the curtain is a white sheet and the interior of the room is not perceptible. A light object (dish) held near the window on the inside, however, is readily seen from the outside.

A second and related characteristic is that, in order for the screen to function properly, some distance between the target and screen is essential. Even properly toned items, to remain concealed, must have both high reflectance surfaces, e.g., windshields, headlights, etc., and deep shadow areas covered to minimize form-revealing contrasts and attention-drawing reflections.

Screens are designed to permit the total installation to be blended into its background. The Screens are colored, textured, and patterned to assist in disguising their plan or form and to present a natural appearance. In effect, one is trying to bring the ground up over the target. Screens of any appreciable size, therefore, require an additional application of foliage or other local material to further break up the planar surface by casting shadows on it and to diminish edging effects where the screen meets the ground.

The center 1/3 of flat top screens contained dense garnish. The outer 2/3 contained garnish progressively thinned out until there was no garnish at the edge. Earlier drape nets were also thinned out at the edge but to a lesser degree, which often produced a detectable line when observed from the air. The current modular, lightweight screening system is garnished solid to the edge and requires the user to thin out or blend as is needed-but only for one time use or for repeated application to the same item. Screens for use in deserts and snow do not require the texture and scattering characteristics needed for foliated terrains. The use of closer weave or knotted materials, such as shrimp netting, are acceptable for desert or snow camouflage applications. They must still not have a smooth surface, or shine will result, but the texture can approach that of sand. In current practice, the desert and snow screens utilize small incising for all the garnish patterns. The Woodland screens employ a mix of small and large incising to simulate blade-like and leaf-like geometries occurring in nature. The snow screen incorporates a special white garnishing which simulates the reflectance of snow in the near ultraviolet as well as the visible regions of the electromagnetic spectrum. One side of the snow screens has all-white garnishing, while the other side (mixed color side)

contains some forest green and wood-land tan patterns on a predominantly white background; this side is used to simulate partial snow cover. The snow screens also employ specially designed components for easier use in extremely cold environments. The color specifications for desert screen color patterns are the result of studies of U.S. and Middle Eastern desert terrain colors.

Each lightweight screening system includes a support system for elevating the screen above the equipment that is being camouflaged and for fixing the edges to the ground or to adjoining screens (see Figure 3). The support poles are sectional, with one to three pole sections typically used, with a three-armed batten spreader assembly, to support camouflage screens. The edge joining of two screens is accomplished using the quick-connect-disconnect (QCD) device; the QCD consists of brackets permanently attached to the net edges, and pins attached to separate lanyard cords. When the QCD's are assembled, with all the pins oriented in the same directions, disassembly is quickly accomplished by pulling on the appropriate end of the lanyard cord.

Selecting screen size for application to equipment is usually under-estimated. (See Figures 1 and 2 for physical data on camouflage screens.) The installed screen, in most instances, to achieve a concealed target and blended installation, must be tied into existing terrain features at an angle to the ground of less than 60° and preferably closer to 30°. The height versus the area of an installation is important. Where choice of position permits, natural defilade should be sought. In open terrain there is no solution to this problem.

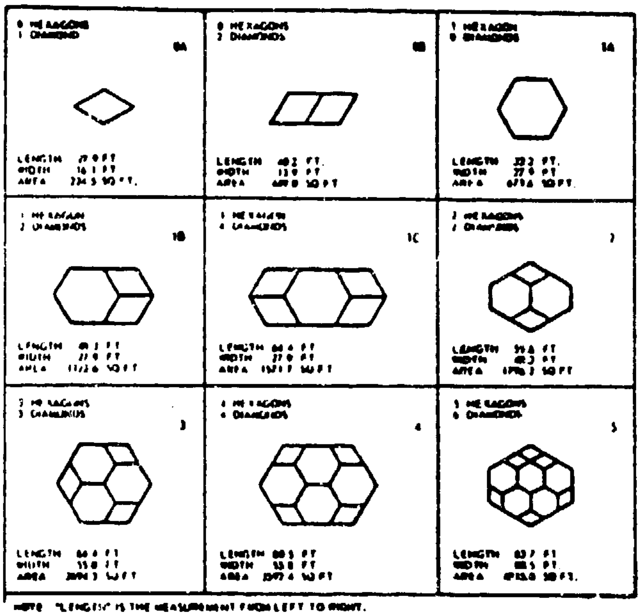
While screens have been improved in the areas of color, texture, weight, bulk, water absorption, durability, reliability, and spectral response, it is logistically possible to supply only a limited variety of such material. Localization is necessary, therefore, to achieve good context with background. Finally, the installation and removal of screens require work and time. If the installation is to remain effective, it must be constantly repaired and maintained.

Camouflage screens are a valuable, though limited, solution to conceal-ment. They are not effective in controlling heat emissions, sounds, and chemical signatures. They also require the item to remain in a static position, whereas other more dynamic camouflage is required for combat equipment subject to constant movement and engagement with an enemy.

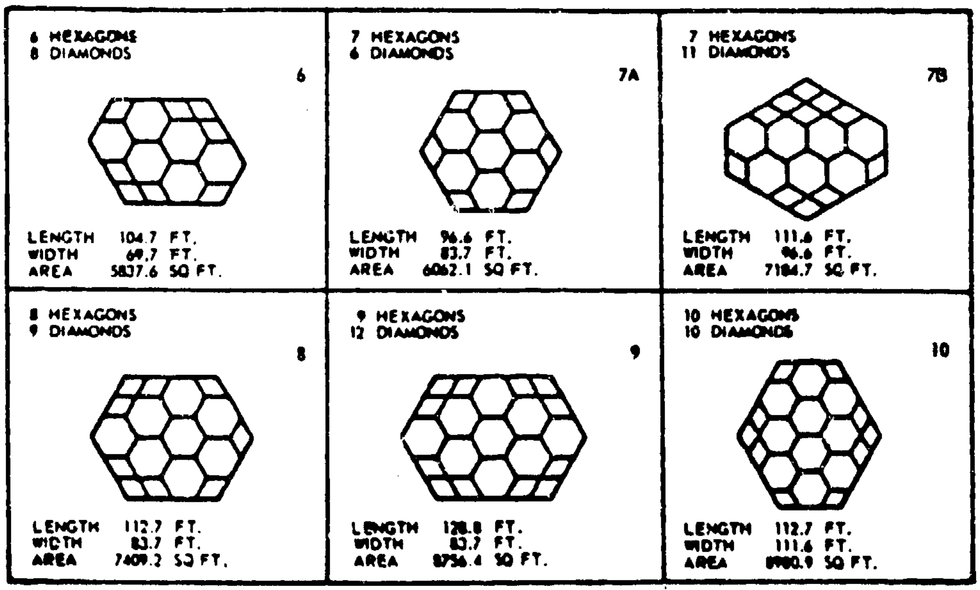
TITLE: CAMOUFLAGE SCREENS (NETS)	DATA SHEET: 2000
	PAGE 4 OF 7

EXPERIENCE:

Nearly all armies employ camouflage screens. Some provide materials which troops combine to produce screens; others provide mass-produced end products. Currently, all nets have concealment capacity in the visible range, and most have concealment capacity in the near-IR and UV ranges. In addition, the newer army screens have has good response not only in the UV, visible, and NIR regions, but some also are effective in the radar region of the spectrum. Further information is available from the experts at TROSCOM's BRDEC on the specific response of individual screens available to the Army.



NOTE "LENGTH" IS THE MEASUREMENT FROM LEFT TO RIGHT.



NOTE "LENGTH" IS THE MEASUREMENT FROM LEFT TO RIGHT.

Figure 1 CONFIGURATION DATA

WEIGHT AND VOLUME

Weight and volume of one packaged camouflage screen system is:

65 lb.; 7.1 cu. ft. (woodland and desert)
85 lb.; 7.1 cu. ft. (snow)

Weight and volume of one packaged camouflage support system is:

70 lb.; 3.3 cu. ft. (woodland and desert)
85 lb.; 3.3 cu. ft. (snow)

General formula for calculating the modular dimensions necessary for camouflaging an item of equipment.

Module(s) Length = 4H + L

Module(s) Width = 4H + W

H = Height of the equipment item

L = Length of the equipment item

W = Width of the equipment item

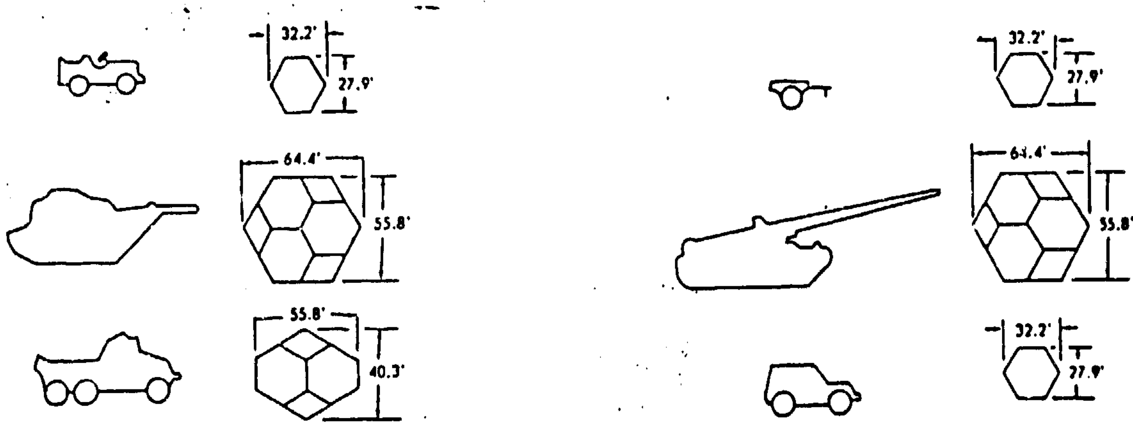


Figure 2 TYPICAL APPLICATIONS

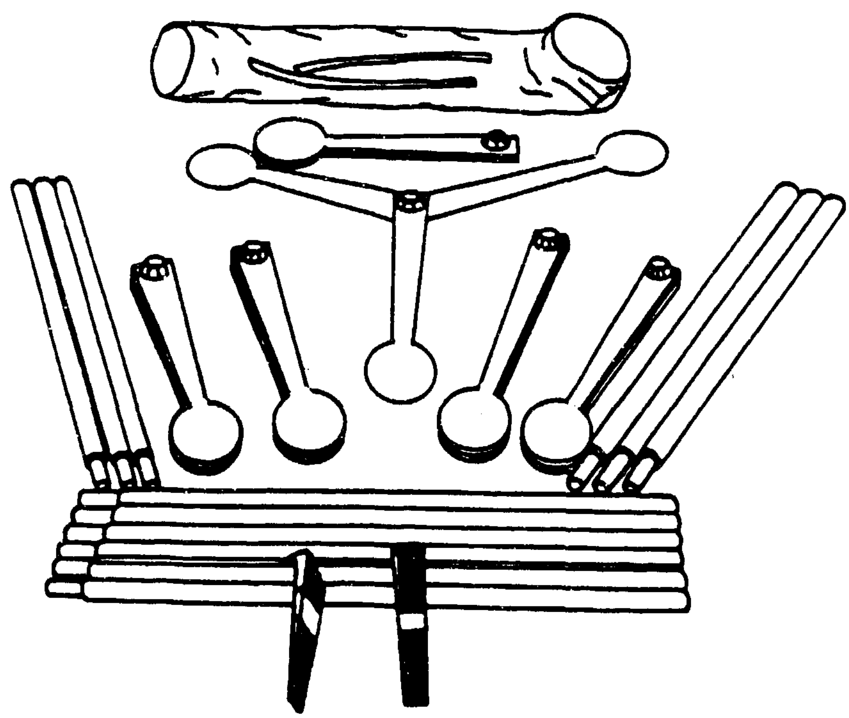


Figure 3a Support System Components: Carrying Case, Batten Spreaders, Poles, and Stakes

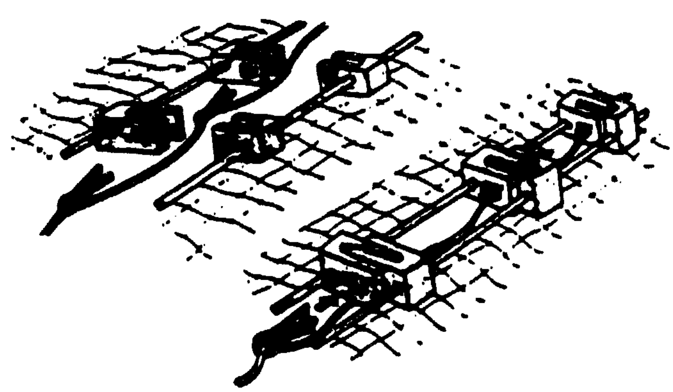


Figure 3b Quick Connect-Disconnect System: Brackets Attached to Edge of Net and Pins Attached to Lanyard Cord

TITLE: CAMOUFLAGE FOLIAGE BRACKETS AND SPRING CLIPS	DATA SHEET: 2001
	PAGE 1 OF 1

Camouflage Technique ☐ Camouflage System ☒ Camouflage Material ☐

PURPOSE:

The brackets are used for attaching natural or synthetic camouflage materials to items of military equipment. Spring clips are used for the same purpose on gun tubes.

POTENTIAL APPLICATION:

To all items of military equipment.

DESCRIPTION:

This materiel is useful for attaching foliated twigs and branches to equipment, or for securing pieces of netting and other synthetic garnishments.

The camouflage bracket assembly described by MS-39322 is a general purpose materiel for all items of equipment.

The spring clip defined by MIL-C-12073C was designed for use when camouflaging armored vehicle gun barrels, e.g., 120 mm, 90 mm, and can be used on other structures as well.

EXPERIENCE:

This materiel concept evolved from the practice of attaching local foliage to armor during WWII. The U.S. Army in Europe welded Landing Mat to the sides and turrets of tanks to make this practice more convenient. Shortly after the war ended, experimentation by the Engineer Research and Development Laboratories evolved the simpler bracket and spring clips system. Foreign countries have adopted and used the system and acceptance by the U.S. Armored Forces is growing. It is a good solution for mobile equipment during actual engagements, especially when evergreen foliage is used.

OTHER CONSIDERATIONS:

There is the requirement for proper installation of the foliage and there will be some interference with clear fields of vision. It is an inexpensive materiel approach, but does shift the burden of proper employment and work onto the field troops.

TITLE: CAMOUFLAGE COVERS FOR HIGHLY REFLECTIVE SURFACES	DATA SHEET: 2002
	PAGE 1 OF 2

Camouflage Technique ☐ Camouflage System ☒ Camouflage Material ☐

PURPOSE:

To minimize the probability of detection by suppressing the glint from highly reflective surfaces such as aircraft canopies and windshields.

POTENTIAL APPLICATION:

Any surface that is inherently glossy and reflective (such as glass) and cannot be painted (due to operational requirements) should be covered to block the reflection of sunlight when not in use. Each wheeled vehicle should employ a set of glare covers for its window areas and head-lights. Aircraft canopies should be covered whenever the aircraft is parked.

DESCRIPTION:

A set of covers should be either: a) built into the design of equipment so that installation is expedient and components are not misplaced, or b) furnished with the item as a kit that crews can carry on board and then install when the item is parked/stationary. Materiel Developers should require glare covers to be an integral component of new systems. These covers should be fixed to the system so that crews need only to "drop" them in place like a curtain. For example, a glare cover for a truck can be rolled and tied on top of the cab during transport, and unrolled and secured when the vehicle stops.

For systems such as helicopters, where exterior stowage is not feasible, the covers should be packed and stowed on board, within easy reach of the crew members. In all cases, a glare cover must be accessible or crews will not use them.

The covers can be made from fabric, metal, or plastic and the choice should be left up to the system designer. Materiel Developers can specify a type of fabric is weight and stowage must be minimized, as in the case of aircraft. Most glare covers will be made of a coated fabric or a lightweight rip-stop nylon. All covers should be camouflaged on their exterior (visible face) to match the painted portion of the parent system. Color, pattern and gloss characteristics should match the specifications of the camouflage paint. Durability is also important, although the covers should be inexpensive and non-repairable items.

TITLE: CAMOUFLAGE COVERS FOR HIGHLY REFLECTIVE SURFACES	DATA SHEET: 2002
	PAGE 2 OF 2

Materiel Developers can require these covers by writing them into their system specifications. A design should be prepared and Level 3 drawings furnished to the Government as part of the item's TDP. This will allow future competition for spares and resupply.

EXPERIENCE:

Prototype canopy covers have been developed for fielded systems and subsequent evaluations have identified their significant contribution to signature suppression.

OTHER CONSIDERATIONS:

Canopy covers for aircraft must be fitted to closely match the shape of the canopy, since fluttering of a loose cover may abrade the surface of the canopy. Also, dust or sand particles may become trapped and scratch the surface. A tight seal around the perimeter of the canopy cover will prevent this from occurring.

TITLE: CAMOUFLAGED COVERS FOR COMPONENTS THAT CANNOT BE PAINTED WITH SCAPP	DATA SHEET: 2003
	PAGE 1 OF 2

Camouflage Technique [ ] Camouflage System [x] Camouflage Material [ ]

PURPOSE

To minimize the probability of detection of components that cannot be painted with SCAPP due to unusual configurations or performance requirements.

POTENTIAL APPLICATIONS:

Equipment or components that are mounted onto or transported by SCAPP painted vehicles must also comply with the Army's SCAPP requirement. However, many components cannot be painted due to their complex shape, or interchangeability of components, or performance requirements of the item. Some systems that exhibit these characteristics are as follows:

(a) Reactive armor tiles mounted on the exterior of tanks or personnel carriers.

(b) Palletized ammunition such as tank or howitzer rounds.

(c) Rotor blades of parked aircraft.

(d) Parabolic dish antennas for SATCOM systems.

DESCRIPTION:

Each of the above components cannot be painted with SCAPP. Items (a) and (b) cannot be painted due to the interchangeable nature of the components. When items are identical and interchangeable, the specific location of the item cannot be defined and, therefore, SCAPP cannot be applied. The best solution is to paint all of the components one color (Green 383) and provide a fabric cover that will be installed over the single colored items. The fabric cover will provide SCAPP that will blend with the SCAPP of the parent vehicle.

Rotor blades of aircraft may be SCAPP painted to provide camouflage when the aircraft is parked. However, an alternative is to paint the rotor blades with a lusterless black and provide fabric rotor blade covers that can be installed by the crews when the aircraft is parked.

TITLE: CAMOUFLAGED COVERS FOR COMPONENTS THAT CANNOT BE PAINTED WITH SCAPP	DATA SHEET: 2003
	PAGE 2 OF 2

It is a "tube" or sock that slides on the blades and is printed with SCAPP on the "top" side of the cover (the side facing upward). Materiel Developers should require that their contractors evaluate both or perhaps provide both for evaluation during the operational testing phases of new equipment.

SATCOM (or any dish-type) antennas exhibit a very prominent visual signature. Due to its shape and size, these types of antennas are easily detected and recognized. SCAPP application may not be possible, however, due to performance requirements of the antenna (SCAPP can cause a higher surface temperature due to solar loading of the lusterless (highly absorptive) paints). This solar load may cause distortion of the antenna surface and impact the strength of the signal. If SCAPP cannot be applied, a fabric cover should be manufactured to comply with the SCAPP requirement. This fabric must be transparent to the systems' signal frequencies but will provide a visible surface to which SCAPP can be applied. Materiel Developers should consider this component for all newly manufactured dish antennas.

EXPERIENCE:

Prototype covers have been fabricated to cover the Bradley Armor Tiles, the 120 mm Ammunition Pallets carried by HEMTT, and Blackhawk (UH-60) rotor blades. Different fabrics were used based on the performance requirements of each system. For helicopters, lightweight rip-stop material is best, while heavier and more tear resistant fabric is required for the Bradley and HEMTT covers. All were successfully tested and will be fielded within the 1990 time frame. Prototype ballistic covers were also fabricated for the Ammunition Pallets at the request of TRADOC. This type of a cover can not only provide good camouflage protection, but can also enhance the survivability of palletized ammunition against artillery fragments or small caliber fire.

TITLE: RADAR ABSORBING MATERIAL-FLAT PLATE, RESONANT	DATA SHEET: 3000 PAGE 1 OF 2

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material ☒

PURPOSE

To reduce radar cross section over a narrow band of frequencies.

POTENTIAL APPLICATION:

For use in reduction of radar signature against a given threat frequencies.

DESCRIPTION:

Flat resonant radar absorbing material (RAM) is of two constructions. The first is the Salisbury screen which consists of a thin sheet of lossy material spaced one-quarter wavelength from a surface of high conductivity. The thin sheet consists of a mixture of carbon, graphite, or conductive wires having a surface resistance of 377 ohms per square. The highly conductive surface is usually the mounting surface. The second construction, sometimes called a Dallenback layer, is a homogeneous lossy material backed by a metallic surface. The lossy material is usually a carbon foam or silicone rubber mixture.

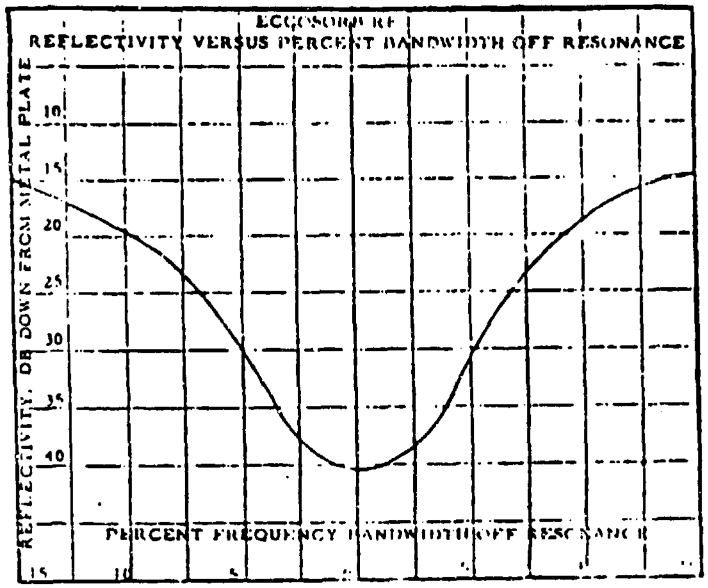
The Salisbury Screen is the lightest and most flexible, weighing 0.05 to 0.5 pound per square foot. The solid laminate layer, although much heavier, withstands a more severe environment.

The Dallenback construction tolerates the most extreme environment. The laminate is generally based on a silicone composition which will withstand temperatures of -65° to 325°F. It is not affected by outdoor exposure and is completely impervious to moisture.

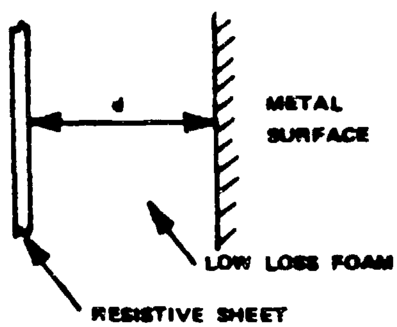
Rugged Salisbury constructions have been fabricated; however, flexibility is sacrificed.

Resonant RAM affords the Smallest thickness, 2 to 1/8 inches over a frequency range of 2 to 18 GHz.

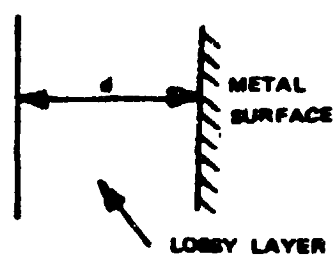
Typical radar response and construction are shown in the following illustrations:



<u>Salisbury Screen</u>



<u>Dallenback Layer</u>



The lossy Salisbury sheet is generally protected by a strong nylon reinforced plastic. The RAM assembly is very flexible thereby facilitating any surface mounting. The standard absorber is designed for best performance at normal incidence. Standard sizes of 24" x 24" are commercially available. Mounting can be easily made with adhesives having high initial tack.

TITLE: RADAR ABSORBING MATERIAL-FLAT PLATE, BROADBAND, GRADED	DATA SHEET: 3001
	PAGE 1 OF 3

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material ☒

PURPOSE:

To reduce target radar cross section over a broad band of radar frequencies.

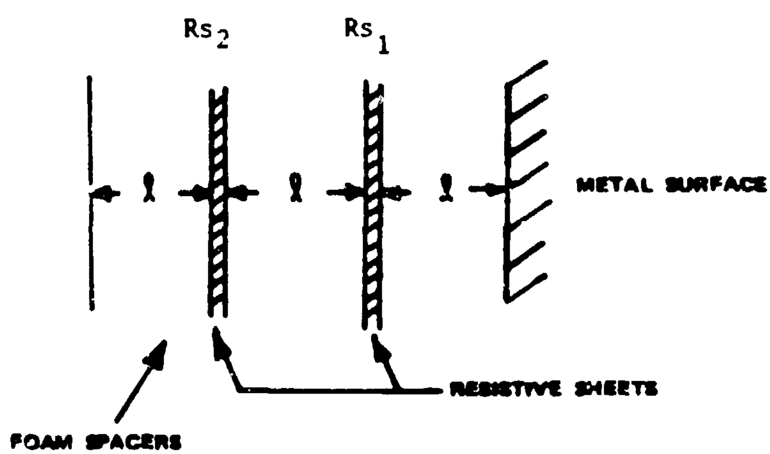
POTENTIAL APPLICATION:

Tanks, shelters, vehicles with large corner geometry.

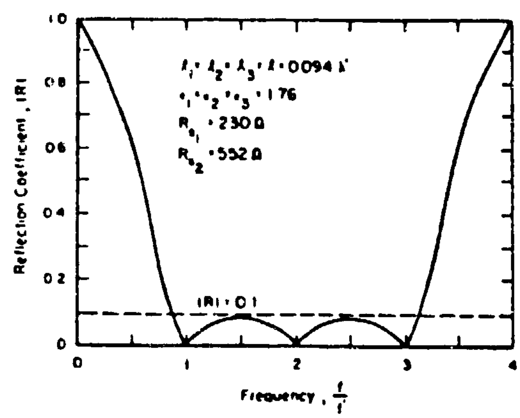
DESCRIPTION:

Absorption over a broad frequency band can be obtained by gradually increasing the loss as the incident field propagates into the material. This loss can be either distributed or lumped into discrete layers of thin resistive sheets oriented parallel or perpendicular to the direction of propagation of the incident wave.

One type, the Jaumann design, utilizes thin resistive sheets, analogous to the Salisbury screen. The resistance of the sheets decreases exponentially toward the metallic mounting surface.



The frequency dependence for such an absorber is shown in the following graph. The input impedance of an absorber of this type can be obtained using the theory for arbitrary layered media. The upper frequency limit occurs when the spacer thickness is electrically one-half wavelength. The lower limit occurs when the overall thickness is less than one-half wavelength.



Normal-incidence reflection coefficient of a three-layer Salisbury screen versus frequency.

Typical construction utilizes closed cell polyethylene spacers and a film deposition of carbon for the resistive sheets. Sheet sizes are 24" x 24", and for an overall thickness of 1 3/16 inches weighing 0.5 pound per square foot, will provide less than 2% reflectivity from 2.5 to 12 GHz. The construction is weatherproof, fuelproof, and flexible.

Numerous solutions for inhomogeneous configurations have been investigated and was generally categorized into linear, exponential, quadratic, etc., distributions. However, because of nearly impossible manufacturing techniques, the best approximation is achieved through the fabrication of several discreet layers having electrical properties that approximate the desired mathematical distribution.

Although a gradient is implied. it is nearly impossible to match the first outer layer to free space; therefore, the mechanism of continuous absorption is not fully realized. Consequently, the layer dimensions must be selected to provide a vector sum reflection at the initial interface to cancel the original reflected component.

The loaded foam layered construction is available in flexible foam assemblies. The thickness is inversely proportional to frequency; 1/4 inch for 20 GHz and above, and 4 1/2 inches for 0.6 GHz and above. Respectively, the weight is 0.1 to 2 pounds per square foot.

Use of honeycomb spacers can provide graded or Jaumann absorbers with high structural integrity. For the graded, thick single layers of phenolic honeycomb are dipped and successively re-dipped to lesser depths in lossy film forming materials to achieve the desired dielectric gradient. For an overall thickness of 1 inch, weighing 2 pounds per square foot, such a panel exhibits a column compression strength of 3800 pounds per inch.

Efforts are currently within the state-of-the-art to develop composite laminates exhibiting radar absorption capabilities in the 2-35 GHz range at thicknesses of 0.5 inch or less.

TITLE: RADAR ABSORBING MATERIAL-FERRITE	DATA SHEET: 3002
	PAGE 1 OF 2

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material ☒

PURPOSE

To reduce target radar cross section over a broad band of radar frequencies.

POTENTIAL APPLICATION:

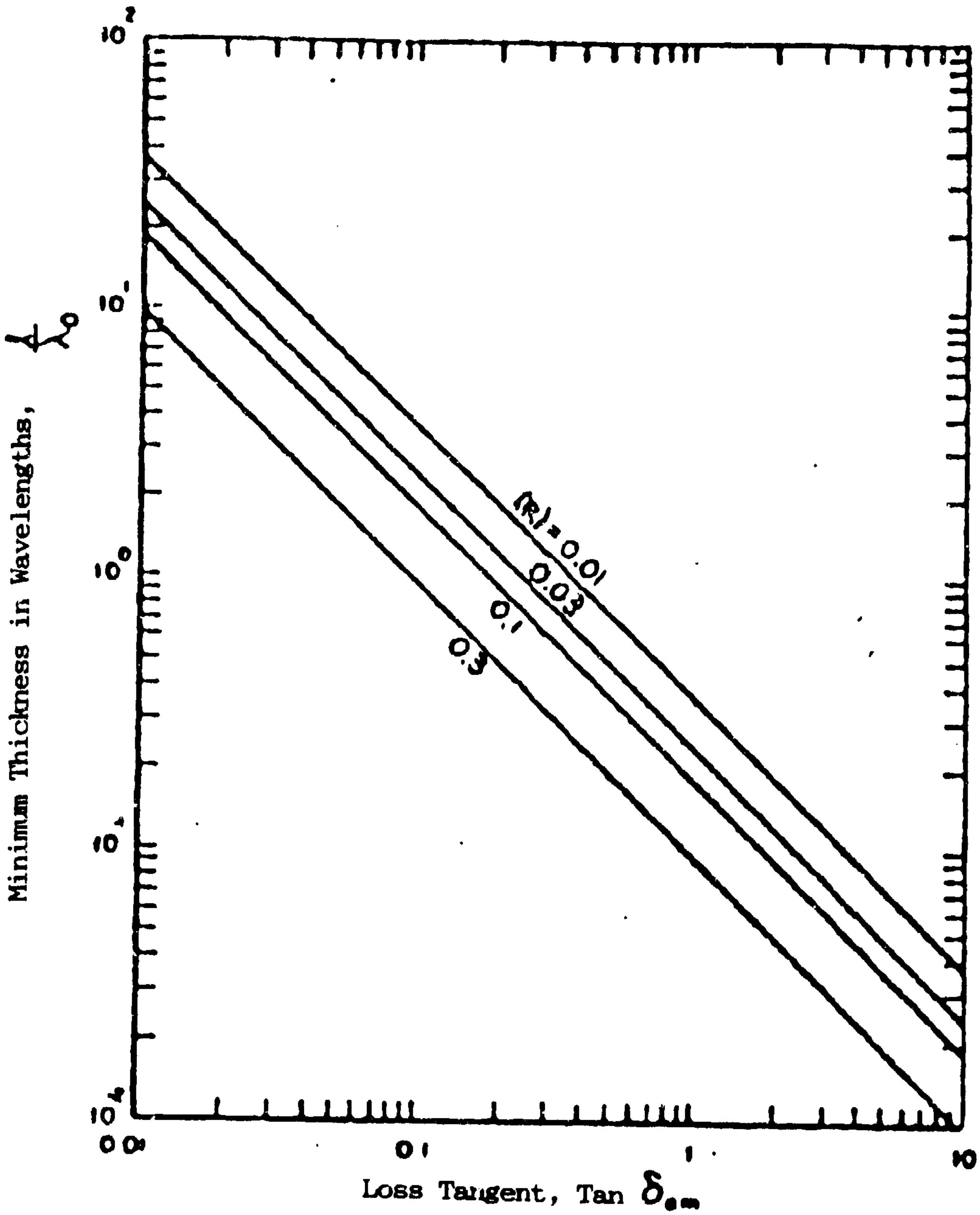
Tanks, shelters, vehicles, with large corner geometry.

DESCRIPTION

Neglecting any variation of basic electrical properties of a material, permeability (μ) and permittivity (E), the reflection from a material is zero, if μ = E. With sufficient thickness and large enough loss so that the reflection from any metal backing can be neglected, a very thin broadband absorber can be fabricated. In general, the only materials capable of such accomplishment are the ferrites. A lossy mixture of a high μ (ferrite) material, and a high E (barium titanate) material can be used effectively for wave absorption if the ratio μ/E is equal to that of free space. The mixtures constitutes a physical discontinuity, but the wave enters it without reflection. The velocity of the wave is reduced and large attenuation can occur in a short distance. The following graph gives curves of minimum electrical thickness versus loss tangent for various desired values of reflection.

A commercially available ferrite absorber has a thickness of 0.04 inch, weight 1.0 pounds per square foot, and averages 10% reflection from 4 to 10 GHz. Although available in thin sheets, tile varieties offer good performance at low frequencies.

TITLE: RADAR ABSORBING MATERIAL-FERRITE	DATA SHEET: 3002
	PAGE 2 OF 2



MINIMUM THICKNESS OF $\mu = \epsilon$ ABSORBER NECESSARY TO GIVE A SPECIFIC NORMAL INCIDENCE RELECTION COEFFICIENT VERSUS THE LOSS TANGENT OF THE MATERIAL.

TITLE: RADAR ABSORBING MATERIAL-LOW DENSITY	DATA SHEET: 3003
	PAGE 1 OF 1

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material ☒

PURPOSE

To reduce target radar cross section over a broad band of radar frequencies.

POTENTIAL APPLICATIONS:

Tanks, shelters, vehicles, with large corner geometries.

DESCRIPTION:

A good absorber material match to free space can be accomplished by using materials of very low density for which the dielectric constant (E) is very near that of free space. Absorption is accomplished by incorporating a small amount of loss and using relatively thick material, electrically.

Typical examples of this material are hair-mat types consisting of a loosely spaced mat of lossy fibers. Low density plastic foams, such as styrofoam having small amounts of carbon particles have been incorporated. This type of absorber is most suitable for laboratory environments and is not a likely candidate for camouflage application.

A 20dB absorber having an 8-inch thickness will function down to 0.5 GHz. These absorbers are usually limited to about 20dB in performance. Density is about 4 oz per square foot for a 2-inch thickness.

TITLE: RADAR ABSORBING MATERIAL-CIRCUIT ANALOG	DATA SHEET: 3004
	PAGE 1 OF 2

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material ☒

PURPOSE

To reduce target radar cross section over a broad band of radar frequencies.

POTENTIAL APPLICATION:.

Reduce radar cross section in harsh environments; i. e., engine intakes.

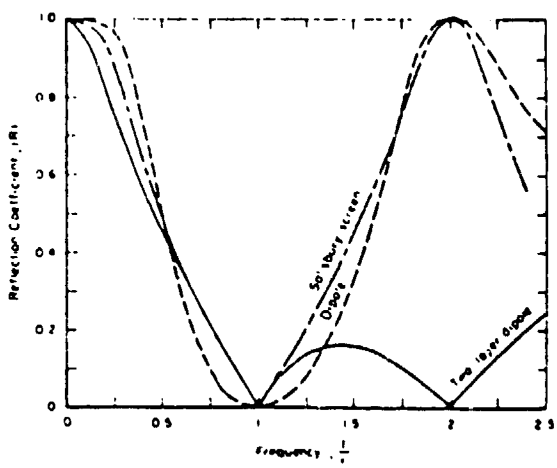
DESCRIPTION:

The advantages of CA material in RAM designs are wider bandwidth, smaller thickness, fewer sheets required, better control of absorption values and the ability to design around thicker skins. The use of CA materials will permit the design of high performing systems that can meet the structural requirements of advanced weapon systems.

These absorbers are characterized by thin sheets of material, usually Kapton, having printed geometric arrays resembling printed circuits, but having specific surface impedances separated by lossless dielectric layers. The Salisbury screen is perhaps the simplest example of CA absorber. However, instead of using resistive sheets, a dipole array of known geometry can, with the use of network theory, be designed to provide specific impedance versus frequency characteristics.

A comparative response of a CA absorber is shown in the following graph.

TITLE: RADAR ABSORBING MATERIAL-CIRCUIT ANALOG	DATA SHEET: 3004
	PAGE 2 OF 2



Comparison of the Frequency Response of Single-Layer Dipole, and Single-Layer Salisbury-Screen Absorbers.

TITLE: RADAR ABSORBING MATERIAL-GEOMETRIC TRANSITION	DATA SHEET: 3005
	PAGE 1 OF 1

Camouflage Technique [ ] Camouflage System [ ] Camouflage Material [X]

PURPOSE:

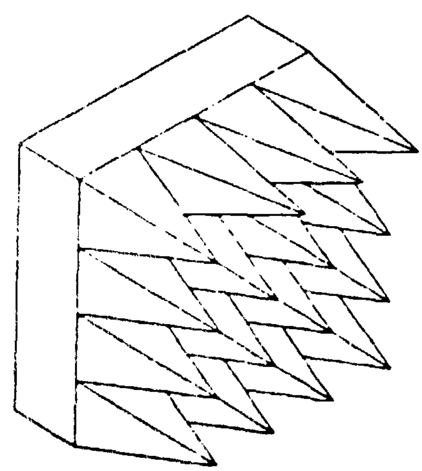
To reduce target radar cross section over a broad band of radar frequencies.

POTENTIAL APPLICATION:

On items/systems where the highest available degree of protection is required and where the absorber's fragility and bulk are not factors.

DESCRIPTION:

In order to achieve lower reflection than is available in most flat plate absorbers (20dB), the subject absorber is characterized by a geometrical transition from free space into a lossy media. This class of absorbers usually takes the form of pyramids or wedges of synthetic sponge rubber or plastic foam which is loaded with an electrically lossy material (carbon). A sketch of a pyramidal absorber is shown below. The geometrical transition may be also combined with an electrical transition by increasing the loss toward the base of the pyramids. Absorbers of this type have reflection losses of 40dB or more for thicknesses of one-quarter free space wavelength. Also better angular performance is available; 40dB up to 50 to 60 degrees. For 1 GHz and up, typical thickness would be 18 inches at about 1.2 pounds per square foot.



Geometric Transition Absorber

TITLE: CAMOUFLAGE PAINT FOR PATTERN PAINTING -- CHEMICAL AGENT RESISTIVE COATING (CARC)	DATA SHEET: 3006
	PAGE 1 OF 2

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material ☒

PURPOSE:

Chemical Agent Resistant Coatings (CARC) will be applied to tactical equipment to provide troops the capability of decontaminating their equipment and returning it to service quickly. CARC will not absorb chemical agents. These agents will simply reside on the surface of CARC and can be washed away with standard decontamination procedures.

POTENTIAL APPLICATION:

All tactical equipment must have SCAPP applied using CARC. An important rule of thumb is this: all three-color (SCAPP) patterns are applied using CARC. There are no authorized exceptions.

DESCRIPTION:

CARC has two principle functions: 1) provide chemical agent resistance to tactical equipment, and 2) provide camouflage colors necessary to comply with SCAPP. CARC is available under two specifications; MIL-C-46168 is a dual component polyurethane that requires mixing prior to application and MIL-C-53039 is a newer single component polyurethane that requires no mixing and is particularly well suited to field touch-up painting. Either specification is acceptable for Materiel Developers to use. It is recommended that production contracts allow contractors this choice (both meet the CARC requirement) since specification of one CARC over the other may result in higher paint application costs. Both MIL specifications call for CARC in a variety of camouflage colors. The most commonly used colors for SCAPP will be Green 383, Brown 383, Black, and Tan 686. These colors are formulated to provide a lusterless surface finish which contributes directly to the effectiveness of the SCAPP system. These colors are designed to provide equipment with natural coloration and low contrast with natural surroundings.

Manufacturers of CARC must submit sample chips of each color from each lot (batch) of paint manufactured. These samples are then tested and qualified for use by Belvoir's Materials, Fuels and Lubricants Laboratory. Materiel Developers should require contractors to furnish Government letters of qualification to demonstrate that the CARC they will be using is fully certified. A Qualified Producers List can be obtained from the Materiels Laboratory, STRBE-VO, at Belvoir.

The proper application of CARC is critical to the performance of this coating system. MIL-T-704 specifies all of the related processes that should be followed to ensure proper application of CARC. Pre-treatment, surface preparation, cleaning, priming, top coat application and curing are all critical steps that must be controlled by contractors. Failure in any of these procedures will result in a failure of the CARC system. Failures such as cracking, peeling, alligatoring, checking, etc. may result when CARC is improperly applied. Materiel Developers should refer to MIL-T-704 in the contract SOW.

To support the quality control and inspection of CARC application, MIL-C-53032 provides a comprehensive application and inspection specification (a process P specification) that will validate whether or not the CARC was properly applied. Materiel Developers should also make this specification a contract requirement. It is an important specification because improperly applied CARC often looks exactly like properly applied CARC. MIL-C-53032 provides the only sure method of testing for CARC performance.

EXPERIENCE:

CARC has been a requirement for all tactical systems since 1981. In 1983, SCAPP and CARC were "married" to form the current camouflage system. Manufacturers have now acquired significant levels of experience and can apply CARC in a responsible and cost effective manner. Depot and General Support painting facilities are now "CARC-only" facilities. Safety and environmental issues have been well documented by industry and Government. A significant cross section of Defense industry now has experience with CARC and can readily respond when CARC is specified in production contracts. Paint manufacturers have been producing qualified CARC for many years and the stock of Government-approved CARC (both commercially and in Government supply channels) is good. CARC has fully replaced the previously used alkyd-enamels as the required coating system for tactical equipment. MIL-C-52798 (alkyd-enamel) has been cancelled.

TITLE: PAINT, CAMOUFLAGE, REMOVABLE, FOR SCAPP	DATA SHEET: 3007 PAGE 1 OF 2

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material [X]

PURPOSE:

The permanent SCAPP of vehicles and equipment that are deployed with Light Divisions or Rapid Deployment Forces may not match the environments where these forces will deploy, e.g., vehicles which have woodland SCAPP being deployed into a desert environment. Removable Camouflage Paint will allow troops to quickly change the camouflage colors of their equipment to more accurately match the local geographic or seasonal conditions.

POTENTIAL APPLICATIONS:

All tactical equipment can be converted to an alternate camouflage scheme if SCAPP has already been applied to the item with CARC. This removable paint does not harm the CARC and it can be removed by application of an ammonia/water solution, or by the decontamination process.

DESCRIPTION:

This removable paint is a water-based (latex) paint that is not hazardous to personnel or equipment. It will be applied to SCAPP equipment by troops in the field. The colors available are white and tan 686. White is formulated to match the UV reflectance of snow. It should be applied at the discretion of the local commander as follows:

a. For snow cover less than 15%, do not apply white paint.

b. For snow cover between 15 and 85%, apply white over the green portion of SCAPP, black and brown remain visible (partial snow condition).

c. For snow cover exceeding 85%, and where there is little vegetation or background cover to conceal vehicles, paint over the entire SCAPP, item will be all white (full snow conditions).

Tan 686 will be applied in the same manner. For desert areas either part or all of the SCAPP should be covered to match local conditions. This paint is especially well suited to training exercises in dry climates (e.g., NTC at FT Irwin, CA) where a temporary color change is desired. The expense of using CARC (or another permanent paint) prior to and immediately after the exercise is avoided.

EXPERIENCE:

This paint is currently available and has been identified as the preferred means of accomplishing an expedient color change in the field. It replaces the specs for hydrocarbon-soluble (gas and diesel) temporary paints that were found to be environmentally unsafe. The ammonia-water solution can easily be neutralized if it is accidently flushed into a wastewater treatment plant.

TITLE: PAINT, HEAT RESISTANT, FOR SCAPP	DATA SHEET: 3008
	PAGE 1 OF 1

Camouflage Technique [ ] Camouflage System [ ] Camouflage Material [X]

PURPOSE:

This special purpose coating will be applied to items that require SCAPP, but cannot be painted using CARC due to high operating temperatures.

POTENTIAL APPLICATION:

All exterior exhaust stacks on vehicles, engine exhaust stacks on vehicles, engine exhaust areas of tanks, and any surface that exceeds 400°F when operating.

DESCRIPTION:

This is a silicon-based paint that will withstand extremely high operating temperatures. (CARC burns off above 400°F and releases noxious fumes.) This paint is available in the standard SCAPP colors (including Tan 686) and should be applied directly to base metal with no primer (there is no Heat Resistant Primer).

SCAPP is designed to be applied to all visible exterior surfaces. Materiel Developers and their contractors should be cognizant of high temperature surfaces on their equipment and paint necessary camouflage with this paint as required.

TITLE: CAMOUFLAGE CLOTH	DATA SHEET: 3009
	PAGE 1 OF 11

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material [X]

PURPOSE

Camouflage cloth is useful for hiding, blending, disguising, or otherwise concealing or covering items of military equipment. Detection by an observer can be denied because the camouflaged item is a close copy of the natural surroundings with respect to color appearance and properties in certain other portions of the electromagnetic spectrum. In those cases where detection is not denied, this material can retard identification of the equipment by obscuring its size, shape or other distinctive characteristics.

POTENTIAL APPLICATION:

This material is complementary to the lightweight screening systems (see Data Sheet 2000), in that it is most suited for: camouflage small items of equipment; for concealing foxholes, tracks, etc.; or for adding to a screen deployment where small, finishing touches are needed.

DESCRIPTION:

Camouflage cloth is a lightweight, vinyl coated nylon or polyester material with the physical properties shown in Table III. Both sides of the nylon or polyester are coated with flexible vinyl films, giving the choice of color combinations shown in Table I. Colors 1, 2, 4, and 6 are formulated for utilization in woodland environments during spring and summer. In addition to the visual color which approximates natural foliage, Colors 1 and 2 have the characteristic shape of the spectrophotometric curve of chlorophyll in the red and near-infrared (NIR) spectral regions (see Figure 2). This relatively large ratio of near-infrared to red reflectance defeats detection by color infrared (camouflage detection) photography.

Colors 1, 3, 5, and 7 are designated fall and winter colors for woodland areas. Color number 1 is included to allow for evergreen foliage and, therefore, should be utilized proportionally as the natural surroundings dictate.

A mixture of Colors 5, 9, and 10 is the general formula for reproducing a tan shade of desert environment; Colors 9, 10, and 12 yield a grayer mixture.

The snow camouflage cloth is designed for use in totally snow-covered environments or in partial snow where the snow covering is partially broken by evergreen foliage, rocks, earth, tree trunks, stumps, etc.

The CIE (International Commission on Illumination) system of color notation is used to quantitatively define the camouflage colors. The chromaticity coordinates, x and y, of each are shown in Figure 1. The usual specification for color tolerance is the locus of points 2.0 NBS units from the target value. This locus takes the form of an ellipse. The 2 NBS ellipse for the dark green color is shown in Figure 1. Ellipses (not shown) for the other colors are centered around the indicated target values and are the same order of magnitude in size and have approximately the same orientation.

The third coordinate of CIE color notation is the apparent reflectance function, Y, sometimes called brightness or lightness. This function is a measure of total visible light reflected from a sample surface irrespective of hue or saturation. (A perfectly white, perfectly diffuse surface theoretically gives Y = 100%). The apparent reflectance specifications for camouflage cloth colors are given in Table I.

Also shown in Table I are the average NIR reflectance specifications for camouflage cloth colors. In addition to the specially shaped spectrophotometric curves mentioned above for Colors 1 and 2, all the colors have been formulated to give NIR reflectances of the same magnitude as the natural environments where they are designed to be used.

Camouflage cloth can be used in either incised or flatstock forms. Small incising, shown in Figure 4 is more commonly used and provides blade-like texture. Camouflage cloth combinations 1/1 and 6/7 are usually given the larger incising (Figure 5) which provides a leaf-like texture.

Camouflage cloth contains radar scattering elements which deny discovery or identification of military equipment by microwave sensors. The cloth attenuates the microwave return to a level approximating natural background return. The radar and transmission properties of incised and flatstock cloth are shown in Figure 3. Radar transparent camouflage cloth is also manufactured.

Vinyl coated nylon or polyester garnish material must be used. This type of radar transparent cloth must be used for camouflaging friendly radar equipment, otherwise the equipment would be rendered ineffective.

All the above-discussed properties must be considered when utilizing this material for a camouflage application. Personal judgement will be involved in selecting the colors of cloth to use and its physical arrangement (geometry) on and about the equipment item. As a general rule, more than one color is required, usually three to five, to achieve the desired innocuous appearance. Straight lines and noticeable planes must be avoided when attaching the cloth to the equipment. When flat-stock is used, special care should be taken to incorporate folds, bulges, shadows and other irregularities to minimize straight lines and planar surfaces. Incised cloth usually gives more effective camouflage because a degree of irregularity, depth, and shadow is already present.

Blending the camouflage with natural foliage and landscape increases the effectiveness. A simple example is that it is easier to hide a weapon in a forest than in an open field. Using the shadow side of the base of a hill is more effective than the exposed top of that hill.

To achieve the natural appearance of depth and shadow, and to fully utilize the radar scattering properties of camouflage cloth, a separation distance of at least one foot should be maintained between the cloth and the item that is being camouflaged.

Table I

VISIBLE AND NEAR INFRARED REFLECTANCE RANGES OF CAMOUFLAGE CLOTH COLORS

Color Name	Color Number	Visible Brightness Average* C.I.E. "Y" Apparent Reflectance, %	Near Infrared Reflectance, %
Dark Green	1	7.0 - 8.5	65 max.
Light Green	2	9.4 - 10.8	65 max.
Khaki	3	21.0 - 23.0	40 - 75
Olive	4	9.7 - 11.3	25 - 55
Tan	5	21.0 - 20.0	35 - 55
Forest Green	6	5.8 - 7.2	25 - 35
Brown	7	10.2 - 11.8	20 - 25
Desert Khaki	9	23.9 - 26.7	25 - 60
Desert Tan	10	33.3 - 36.4	35 - 60
Light Brown	12	18.7 - 21.3	25 - 45
White	13	85.0 - 100	85 - 100

* Wavelengths, in nanometers, used for calculating average near infrared reflectance:

714	751	777	807	836
725	756	783	811	842
730	760	787	816	848
737	764	793	821	855
742	769	797	826	862
747	773	802	831	873

Table II

CAMOUFLAGE CLOTH COLOR COMBINATIONS

WOODLAND CLASS

Cloth	Color Numbers*
Dark Green/Dark Green	1/1
Light Green/Khaki	2/3
Olive/Tan	4/5
Forest Green/Brown	6/7
DESERT CLASS	
Khaki/Khaki	9/9
Tan/Tan	10/10
Tan/Khaki	10/9
Medium Tan/Khaki	5/9
Tan/Light Brown	10/12
SNOW CLASS	
White/White	13/13
Forest Green/White	6/13
Tan/White	5/13

Table III

PHYSICAL PROPERTIES OF CAMOUFLAGE CLOTH

PROPERTY	TYPICAL VALUES	TEST METHODS/COMMENTS
Unit Weight	7-8 ounces/square yard (woodland and desert) 7-8.5 ounces/square yard (snow)	
Water Absorption	1.2 ounces/square yard weight increase (woodland and desert) 2.1 ounces/square yard weight increase (snow)	24 hour or more immersion
Flexibility	Adequate to -40°F	FTMS 191, Method 5204
Breaking Strength	40 pounds	ASTM D-1682, Grab Method
Flame Resistance	Self-extinguishing	
Specular Gloss	1.0 gloss units at 85° 2.0 gloss units at 60° 2.5 gloss units at 60° (white)	
Fungus Resistance	Does not support fungus growth	Test organism is aspergillus niger; FTMS 191, Method 5750
Tear Strength	5 pounds	Modified FTMS 191, Method 5134

* Each property is tested initially, and selected properties are tested after environmental and other exposures such as: accelerated weathering, accelerated aging; accelerated fading, water immersion, petroleum immersion, salt fog exposure, humidity exposure, and fungus exposure. A complete description of test procedures and specifications is given in MIL-C-53004(ME).

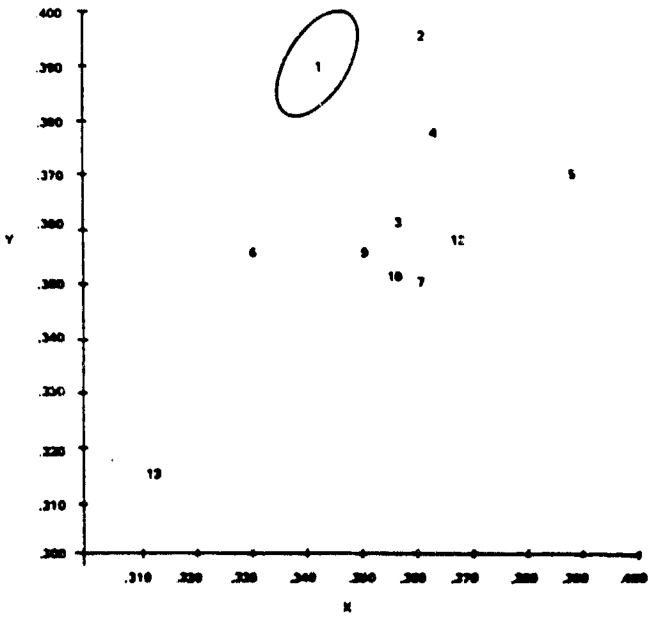


FIGURE 1

C.I.E. Chromaticity Coordinates of Camouflage Cloth Colors

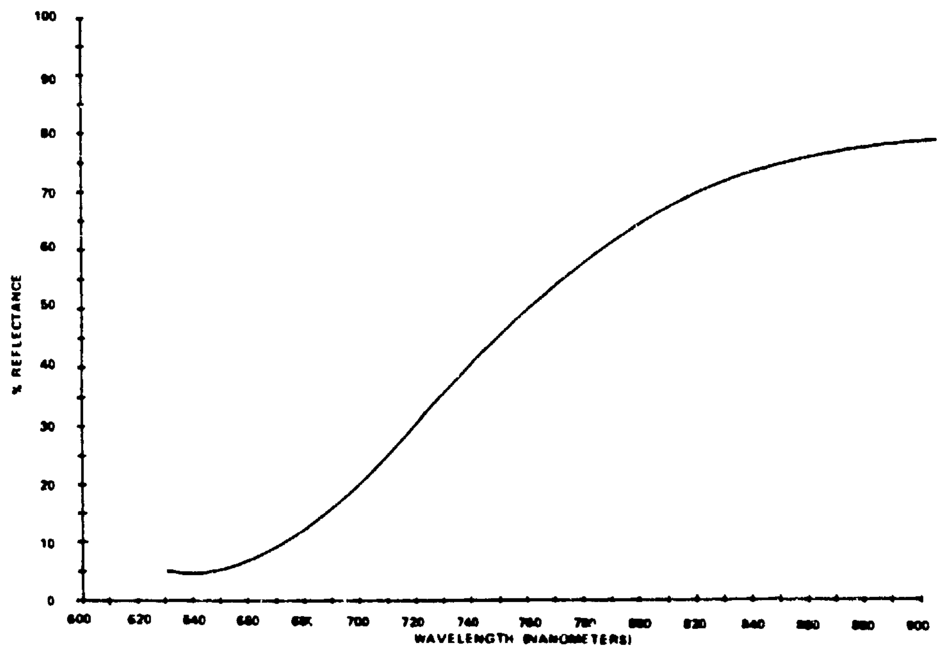


FIGURE 2

Red and Near Infrared Spectrophotometric Curve with Shape Characteristic of Chlorophyll, Typical Values for Dark Green and Light Green Colors of Camouflage Cloth

TITLE: CAMOUFLAGE CLOTH	DATA SHEET: 3009
	PAGE 9 OF 11

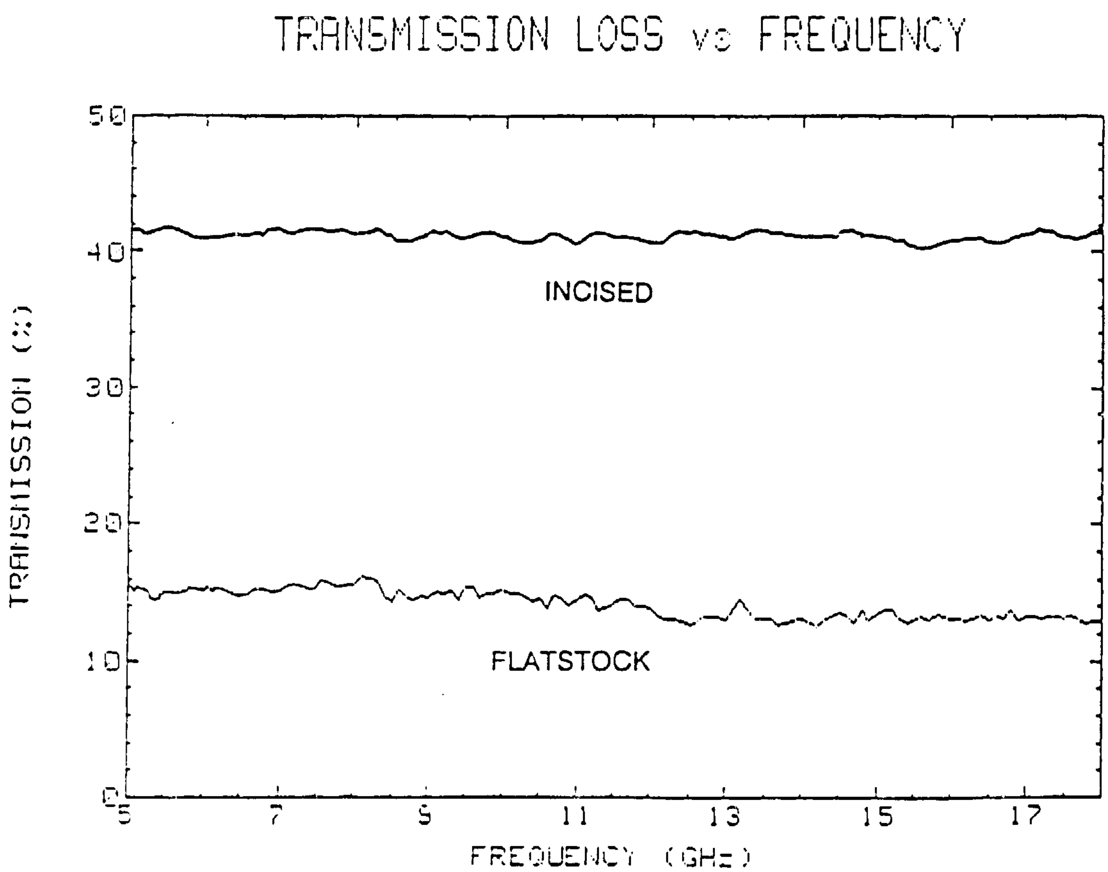


FIGURE 3

Transmission vs Frequency of Incised and Flatstock Camouflage Cloth.

TITLE: CAMOUFLAGE CLOTH	DATA SHEET: 3009
	PAGE 10 OF 11

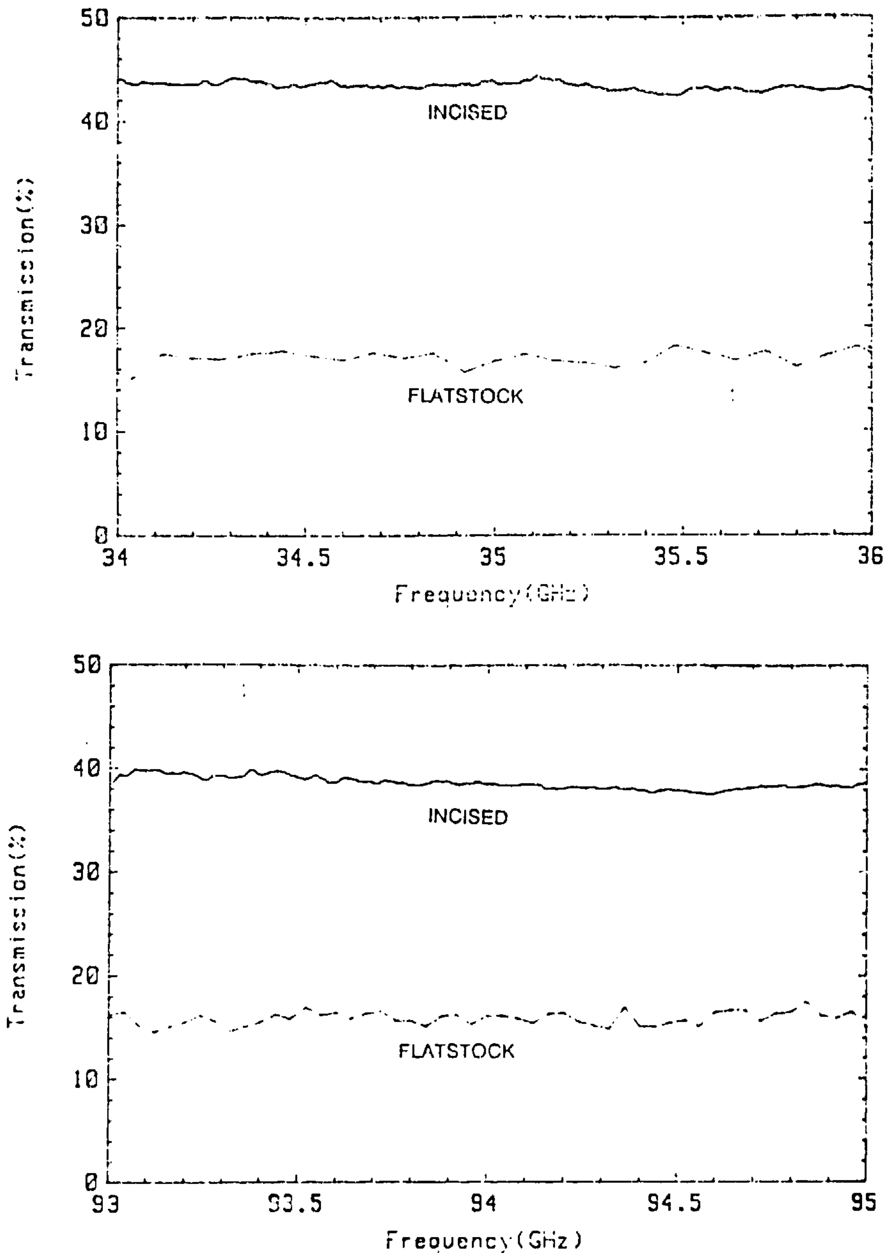


FIGURE 3

Transmission vs Frequency of Incised and Flatstock Camouflage Cloth.

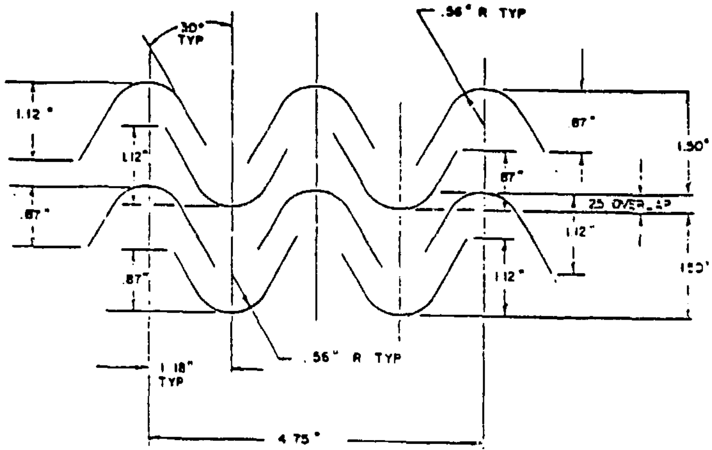


FIGURE 4

Small Incising

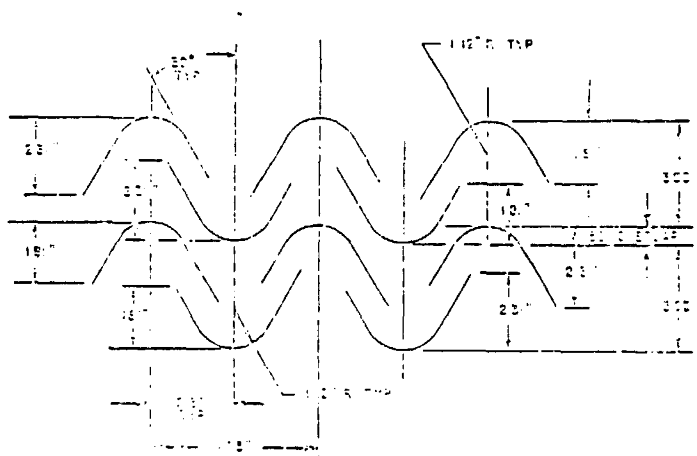


FIGURE 5

Large Incising

TITLE: PAINT, SPECIAL PURPOSE, FOR SCAPP	DATA SHEET: 3010
	PAGE 1 OF 2

Camouflage Technique [ ] Camouflage System [ ] Camouflage Material [X]

PURPOSE:

Special Purpose paints will be required for SCAPP application to equipment where CARC may adversely affect system performance. Specifically a high-reflective paint to minimize solar loading and a Radio Frequency or Microwave Transparent coating may be required.

POTENTIAL APPLICATION:

For large and very conspicuous parabolic-reflector antennas (from 8 ft to 20 ft dia), Radomes, antenna covers on aircraft, missiles such as Hawk and Lance, or other "do not paint" surfaces.

DESCRIPTION:

Many sensitive electronic systems are often temperature sensitive. Lusterless camouflage paint (both CARC and its predecessor, alloyed enamels) are solar absorptive and will cause surface and internal temperatures to rise when a painted item is exposed to prolonged solar loading. To prevent this temperature increase on systems (such as the Hawk and Lance Missiles) a highly reflective paint can be used. It is important, however, that Materiel Developers ensure that important camouflage properties are maintained. The possibility for trade-off does exist, however, since system performance is the first priority.

A second type of paint cam be employed for surfaces that require SCAPP but that also must allow for the transmission of Microwaves. Radomes such as Firefinder and Patriot, and antenna covers on the forward edge of a helicopter tail are good examples. CARC has been shown to be transparent in some wavebands, and should always be considered the first choice by Materiel Developers. There are some commercially available paints that can be adapted for camouflage use, but will not possess CARC properties. These should only be used if CARC and system performance are incompatible.

TITLE: PAINT, SPECIAL PURPOSE, FOR SCAPP	DATA SHEET: 3010
	PAGE 2 OF 2

EXPERIENCE:

Some experimentation has been completed on CARC but most systems such as Radomes and antennas do not currently conform to the SCAPP requirement. Material Developers should not field similar systems unless this issue is addressed, and a SCAPP solution is found. An alternate solution to painted Radomes and antennas is to fabricate a cover that will provide visual camouflage and will not degrade the performance of the system. Firefinder and Patriot both use a fabric cover for the Radome surface during transport.

TITLE: LOW REFLECTIVE COATINGS FOR AIRCRAFT	DATA SHEET: 3011
	PAGE 1 OF 1

Camouflage Technique ☐ Camouflage System ☐ Camouflage Material ☒

PURPOSE:

This paint can be used when the suppression of the near IR signature on aircraft is required.

POTENTIAL APPLICATION:

Currently applied to US Army Aircraft.

DESCRIPTION:

Since most camouflage paint is moderately reflective in the Near-IR waveband, and foliated backgrounds are also moderately reflective, a good N-IR match is easily achieved. The match between these camouflage paints and a low-reflective background, such as the sky, however, is poor. To achieve an adequate NIR match with such backgrounds, Low-Reflective coatings must be used.

An Acrylic Lacquer that is available in two colors: aircraft brown and aircraft black. In addition to the SCAPP colors, aircraft green and aircraft black are also available in chemical agent resistive coatings.

EXPERIENCE:

Low reflective coating has been applied to Army Aircraft in the past, and many aircraft still possess this lacquer coating. Since CARC is now in use for all new or newly repainted aircraft, the lacquer coating is being phased out. In both cases the low-reflective aircraft colors have been developed to counter the NIR threat of the Russian STRELLA missile, which is a heat seeking missile that uses a lead sulfide (Pbs) sensor.

OTHER CONSIDERATIONS:

Currently, this type of low-reflective coating is only available in very dark (Aircraft green and black) colors. The use of this color conflicts with and precludes the application of SCAPP (or any camouflage pattern painting) to aircraft. The Army aviation community has expressed a desire to conform to the SCAPP requirement. Studies are underway to resolve this conflict.

TITLE: SCAPP APPLICATION TO FABRIC COMPONENTS OF TACTICAL EQUIPMENT	DATA SHEET: 3012
	PAGE 1 OF 2

Camouflage Technique [ ] Camouflage System [ ] Camouflage Material [X]

PURPOSE:

To provide an increased level of survivability for tactical equipment by applying SCAPP to fabric components. SCAPP for these components must match the painted pattern that is applied to hard surfaces in order to provide maximum camouflage effectiveness in the visual spectrum.

APPLICATION:

All externally visible fabric components such as soft top cab covers, cargo covers, soft doors, and transport covers for tactical wheeled vehicles.

DESCRIPTION:

SCAPP is a camouflage scheme that must be applied to all visible surfaces of tactical equipment (see Data Sheet 1007). This requirement is easily satisfied by painting patterns onto the hard surfaces of equipment. However, many items of tactical equipment (such as trucks) have protective fabric components as the exterior surface. In order to comply with Army camouflage policy, SCAPP must be applied to fabric components as well.

This can be accomplished in two ways: 1) by pre-printing the SCAPP pattern onto fabric, then assembling (sewing) as usual; or 2) by coating the SCAPP pattern onto the top surfaces of the fabric using a "painting" or "coating" process. Both techniques will require the use of a numeric controlled application process since traditional printing and one-color coating cannot deliver a non-uniform, non-repeating SCAPP pattern.

In either case, the finished product must possess identical color and gloss characteristics as the parent item's painted surfaces. The durability and performance of these fabric components must also be clearly specified. New technology in synthetic fabrics can deliver a fabric cover that is extremely rugged and will keep its appearance over many years. SCAPP can be applied to these synthetic fabrics and the result will be a fabric component that will not change colors, bleach, or fail after only a short time in the field. Materiel developers should specify SCAPP as a requirement for both hard metal surfaces and soft fabric components in spite of the long-standing view that fabric components cannot be camouflaged.

TITLE: SCAPP APPLICATION TO FABRIC COMPONENTS OF TACTICAL EQUIPMENT	DATA SHEET: 3012
	PAGE 2 OF 2

EXPERIENCE

Prototype fabric covers have been developed by BRDEC as part of a technology exploitation program. Several manufacturers have commercial processes that can produce a SCAPP-applied fabric cover. Cover kits have been developed for HMMWV, CUCV, cargo trailers, and larger cargo trucks (2.5 and 5-ton). The development of these kits demonstrate that industry can respond to the SCAPP requirements for fabric components in a cost effective manner.

APPENDIX C

REGISTER OF CAMOUFLAGE TESTING FACILITIES

There are a number of Army facilities available to the system developer which can test and evaluate the effectiveness of a camouflage treatment applied to a particualr item or system. Table C-1 is an index to some of these facilities, which are described in subsequent pages, one page for each individual facility. The primary purpose in listing these facilities is to acquaint the system developer/manager with their capabilities. It is recommended that the system developer/manager coordinate with USA BRDEC on which facilities are appropriate to test specific capabilities and with testing personnel (TECOM) on availability of facilities and the possibility of combining camouflage tests with other necessary performance tests.

Table C-1. Index to Camouflage Testing Facilities.

FACILITY CAPABILITY	FACILITY ID NUMBERS
Acoustic Camouflage	2, 18
Cold Region Tests	3
Fabric, Textile Tests	17, 30
Image Intensifier Tests	9, 12, 15,
IR Sensor System Evaluation	20
IR Signatures	1, 5, 6, 8, 10, 11, 22
Laser Guided Weapon Homing Tests	4, 7
LLL TV Test	9
Magnetic Signatures	18, 23
Photographic Image Evaluation	19
Radar Cross Section	26, 27, 29
Radar Imaging	27
Seismic Signatures	18
Sonic Signatures	18
Spectral Reflectance	24, 26, 28
Thermal Images Test	9, 13, 16, 25
Tropical Environmental Tests	21
UV Signatures	6, 16
Visual, Optical Tests	8, 16
Visual Terrain Model	14, 16

TEST FACILITY: Infrared Imaging Camera		FACILITY NO. 1
FACILITY LOCATION: Fort Knox, KY	ORGANIZATION: USA Armor and Engineer Board ATZK-AE-IN	
TELEPHONE: AUTOVON 464-3228 (502) 624-3228		

This is a compact video compatible infrared imaging system consisting of a scanner and associated electronics control units. The camera outputs standard RS 170 video and is used to record video of thermal images including heat plume signatures of the exhaust from different vehicles. The thermal signatures obtained in this manner can be used for identifying a particular system as a potential target. The facility can be used to identify areas in vehicles with varying degrees of heat build-up which in turn are likely areas of terminal homing by IR seekers.

TEST FACILITY: Acoustics and Magnetics Laboratory		FACILITY NO. 2
FACILITY LOCATION: Dover, NJ 07801	ORGANIZATION: USA Armament Research, Development and Engineering Center Laboratory Section SMCAR-AEC-TIL	
TELEPHONE: AUTOVON 880-4955 (201) 724-4955		

This facility provides capability for the design, development and testing of analog and digital, acoustically oriented instrumentation. Limited capability exists for real-timedata acquisition and reduction of acoustically generated data.

Dedicated equipment is of the general instrumentation type, suitable for the generation and measurement of amplitude and time varying signals compatible with the specialized instrumentation undergoing development testing.

TEST FACILITY: Cold Regions Test Center		**FACILITY NO.** 3
FACILITY LOCATION: Fort Greely, AK **TELEPHONE:** AUTOVON (317) 872-3219 (907) 872-3219	**ORGANIZATION:** USA Cold Regions Test Center Materiel Test Directorate STECR-MT	

USACRTC conducts cold regions environmental testing on a variety of military equipment and systems including weapons, vehicles, general and personnel equipment. Facilities include maneuver areas, firing ranges and drop zones.

TEST FACILITY: Electro-Optics Test Facility	FACILITY NO. 4

FACILITY LOCATION: White Sands Missile Range, NM	ORGANIZATION: USA Materiel Test and Evaluation Directorate STEWS-TE-AM
TELEPHONE: AUTOVON 258-5511 (505) 678-5511	

This facility provides test support for electro-optics weapon systems. In particular, the following areas have been supported:

1. Target signature studies,
2. Laser characterization,
3. Laser weapon tracking tests,
4. Night vision devices,
5. Battlefield environment characterization, and
6. Image processing/analysis development.

TEST FACILITY: Signature Measurements and Data Reduction Facility	FACILITY NO. 5
FACILITY LOCATION: White Sands Missile Range, NM	ORGANIZATION: Vulnerability Assessment Laboratory SLCVA-TAS
TELEPHONE: AUTOVON 258-2218 (505) 678-2218	

The instrumentation utilized includes a variety of spectrometers, radiometers, and radiometric imagers in conjunction with digital recording and formatting equipment. Target data processed included: received infrared and ultraviolet information, tracking and position data, meteorological data, and sequence of events timing. Targets evaluated include infrared and ultraviolet radiating targets of interest to weapon systems and countermeasure design and development. In addition, measurements provide basic data for modeling atmospheric transmission through natural and manmade battlefield environments.

TEST FACILITY: Ultraviolet/Infrared Imaging System	FACILITY NO. 6
FACILITY LOCATION: White Sands Missile Range, NM	ORGANIZATION: Vulnerability Assessment Laboratory SLCVA-TAS
TELEPHONE: AUTOVON 258-2218 (505) 678-2218	

The infrared spectral imaging system was modified, creating a slow-scan ultraviolet/infrared imager. The instrument is the first known ultraviolet imager, operating in either the solar band or near ultraviolet regions of the spectrum. It provides over 21,000 spatial resolution elements per frame.

Performance Characteristics

Ranges

I	.2	-	.4 microns
II	1.5	-	5.5 microns

Scan Time: 3.3 frames/sec.
Spatial Resolution: 0.1 degrees; 21,000 elements/frame
Field of View:
Width: 22.5 degrees
Height: 9.5 degrees

TEST FACILITY: Terminal Homing Laboratory	FACILITY NO. 7

FACILITY LOCATION: White Sands Missile Range, NM	ORGANIZATION: Vulnerability Assessment Laboratory SLCVA-TAS
TELEPHONE: AUTOVON 258-2732 (505) 678-2732	

The terminal homing laboratory utilizes electrical and electro-optical test equipment to perform ECM and ECCM testing of electro-optical terminal homing laser guided weapons systems. Data recording capabilities include strip recorders, scope cameras, magnetic tape, video tape, and voice recorders. Electronic test equipment includes wideband oscilloscopes, precision delay generator, programmable synthesizer, computing counting system, as well as the standard laboratory test equipment. Electro-optical test equipment includes visible and near IR lasers, diode sources, and detectors, as well as radiometers, photometers, spectrophotometers, spectroradiometers and standard electro-optical test equipment.

TEST FACILITY: Visual and IR Spectrum Radiometric and Optical Test Facility	FACILITY NO. 8

FACILITY LOCATION: Fort Belvoir, VA	ORGANIZATION: USA Night Vision and Electro-Optics Laboratory AMSEL-NV-D
TELEPHONE: AUTOVON 354-6666 (703) 664-6666	

This facility allows for the complete evaluation of all optical parameters (e.g., distortion field flatness, focal lengths) in both the visual and far infrared spectrum; also optical piece-part evaluation (e.g., homogeneity) at 10.6 microns, radius and curvature, surface figure and astigmatism. The test area covers 1,000 square feet and includes special vibration-free support isolation systems for major subcomponents.

TEST FACILITY: Advanced Image Evaluation Facility	FACILITY NO. 9
FACILITY LOCATION: Fort Belvoir, VA TELEPHONE: AUTOVON 354-3622/3625 (703) 664-3622/3625	ORGANIZATION: USA Night Vision and Electro-Optics Laboratory AMSEL-NV-D

The Advanced Image Evaluation Facility is a laboratory facility designed to measure key system performance parameters of photon imaging systems including low light level television systems, real-time thermal imaging systems and image intensifier systems. The facility is highly automatic with all major testing conditions under computer control. Data output is provided by a hard copy unit interfaced to a keyboard CRT. The key system performance parameters measures are OTF, Limiting Resoution, Display Cosmetics (noise, uniformity) and Signal Transfer Function.

TEST FACILITY: Near Field Thermcgraphic System	FACILITY NO. 10

FACILITY LOCATION: Fort Belvoir, VA	ORGANIZATION: Night Vision and Electro-Optics Laboratory AMSEL-NV-D
TELEPHONE: AUTOVON 354-3622/3625 (703) 664-3622/3625	

This is a calibrated thermal imaging system which measures the amount of heat radiated by all varieties of tactical vehicles and objects in a broad range of geographical backgrounds and under a mix of atmosphereic propagation conditions. It is a highly complex electro-optical test instrument that is housed in its own mobile test laboratory with all the necessary support equipment.

Performance Characteristics (Static Target Measurement)

Min. -14°C
Max. 60°C
Temperature Sensitivity; 0.1°C
Instantaneous FOV; 1 MRAD
Wavelengths:
Min. 3.5 MICM
Max. 12.0 MICM
Scan Time; 4.5 seconds

TEST FACILITY: Far Field Thermographic System	FACILITY NO. 11
FACILITY LOCATION: Fort Belvoir, VA	ORGANIZATION: Night Vision and Electro-Optics Laboratory AMSEL-NV-D
TELEPHONE: AUTOVON 354-3622/3625 (703) 664-3622/3625	

This is a calibrated thermal imaging system which measures the amount of heat radiated by all varieties of tactical vehicles and objects in a broad range of geographic backgrounds. It is a highly complex electro-optical test system that is housed in its own mobile test laboratory with all the necessary support equipment.

Performance Characteristics (Static Target Measurement)

Min. -14°C
Max. 1000°C
Temperature Sensitivity; 0.1°C
Instantaneous FOV; 0.17 MRAD
Wavelengths:
  Min. 3.5 MICM
  Max. 12.5 MICM
Scan Time; 4.5/20 seconds

TEST FACILITY: Electro-Optics Simulator	FACILITY NO. 12

FACILITY LOCATION: Fort Belvoir, VA	ORGANIZATION: Night Vision and Electro-Optics Laboratory Visionics Division AMSEL-NV-D
TELEPHONE: AUTOVON 354-2730 (703) 664-2730	

The electro-optics simulator provides capability for man-machine evaluation of night vision intensifier systems. The facility consists of a 35-foot X 140-foot screen, observer rooms, unique projection systems which can simulate the nighttime tactical visual environment in a controlled and repeatable manner. The imagery used is still imagery of the tactical target background situation and is displayed in wide screen format to provide a search angle of 80 degrees. The inherent contrast of the imagery is degraded by overlaying white light to synthesize atmospheric degradations. The brightness is adjustable to simulate moonlight to overcast starlight conditions. Test subjects occupy up to six observer stations which are furnished with observer response and data acquisition equipment.

Representative of tests conducted are:

1. Detection in recognition thresholds versus light level contrast range in target type.

2. Search effectiveness versus magnification and field of view.

3. Search effectiveness versus look time.

4. Psycho-physiological factors influencing observer response.

TEST FACILITY: Infrared Simulator	FACILITY NO. 13
FACILITY LOCATION: Fort Belvoir, VA TELEPHONE: AUTOVON 354-2730 (703) 664-2730	ORGANIZATION: Night Vision and Electro-Optics Laboratory Visionics Division AMSEL-NV-D

The Infrared Simulator synthesizes two dimensional thermal imagery of significant military targets in the spectral region of 3-15 microns. The imagery can be controlled to precise Delta T. The simulator is used to generate baseline data on man-machine performance of ground and airborne thermal imaging systems.

TEST FACILITY: 3-D Terrain Simulator	FACILITY NO. 14

FACILITY LOCATION: Fort Belvoir, VA	ORGANIZATION: Night Vision and Electro-Optics Laboratory Visionics Division AMSEL-NV-D
TELEPHONE: AUTOVON 354-2730 (703) 664-2730	

The 3-D Terrain Model is made up of 60 sections with a total real area of 2400 square feet. The model measures 40 feet wide by 60 feet long and is constructed on a one-foot urethane foam substrate. The topographical features represent typical middle European features and include a small section of desert. The natural features (i.e., foliage, soil, rocks, etc.) faithfully reproduces the spectral reflection of their real world countries over the spectral region of 0.4 microns to 1.5 microns. Cultural features are presented in a stylized manner and are finished with typical materials. The scale of the model is 400:1, giving a useful simulated area approximately 3 by 4.5 miles. Facility is equipped with a manually positioned 3-axia gantry with a 2 degree of freedom gimball for positioning a simulated flight platform in surveillance system.

TEST FACILITY: Image Intensifier	FACILITY NO. 15

FACILITY LOCATION: Fort Belvoir, VA	ORGANIZATION: Night Vision and Electro-Optics Laboratory AMSEL-NV-D
TELEPHONE: AUTOVON 354-3622 (703) 664-3622	

This instrument generates the modulation transfer function curve for image intensifier tubes and their associated components over a wide range of input light levels. To overcome the inaccuracies at low light levels, the system utilizes a digital synchronous signal reinforcement technique to improve the accuracy of the measurement. The input light target to the intensifier under test is a slit whose width and length are adjustable. The working distance between input and output objectives is variable. It is required that the input photocathode and output screen of the intensifier under test be parallel and on axis with each other. Off axis measurements up to 5 mm are possible for non-inverting tubes, and 10 mm possible for inverting tubes. Periodic photometric calibration of the input light source is essential for proper data generation. Light source color temperature is calibrated to 2870°C. The light level at the target with no filters is 5.9 X 10^{-2}F.C. Six N.D. 1 filters are available for lower light levels. The analyzer system samples 16 discrete spartial frequencies between 0.17 lp/mm and 50 lp/mm. Modes of operation include direct and digital synchronous signal reinforcement. Outputs are available on an oscilloscope, DVM, and print-out onto an X-Y recorder.

TEST FACILITY: Advanced Simulation Center Electro-Optical Simulation System (EOSS)	FACILITY NO. 16

FACILITY LOCATION: Redstone Arsenal, AL	ORGANIZATION: USA Missile Command Systems Simulation and Development AMSMI-RD-SS-HS
TELEPHONE: AUTOVON 746-1200 (205) 876-1200	

This facility provides realistic and precisely controlled environments for the non-destructive simulation of a wide variety of ultraviolet, visible and near infrared sensor systems. Actual sensors are hybrid computer controlled in six degrees-of-freedom while viewing targets under controlled illumination levels, in an indoor simulation chamber and under ambient conditions on an outdoor simulation range. Three-dimensional target simulation is provided on a 32 ft. X 32 ft. terrain/target model transporter which features a variety of topographical and man-made complexes at 600:1 and 300:1 scales, removable model sections, and fixed and moving targets at any desirable scale. A moving projection subsystem provides two-dimensional (2-D) representation. A gimballed flight table, capable of simulating pitch, yaw and roll movements to the sensor airframe, is attached to a transport which moves both vertically and laterally. The terrain/target model is moved toward the flight table to provide the sixth degree-of-freedom. An adjacent high resolution TV/joystick console and helicopter crew station provide a means of evaluating man-in-the-loop guidance and target acquisition concepts.

TEST FACILITY: Chemical Laboratory	FACILITY NO. 17
FACILITY LOCATION: Aberdeen Proving Ground, MD	ORGANIZATION: Engineering Directorate Physical Test Division STECS-EN-PC
TELEPHONE: AUTOVON 298-2868 (301) 278-2868	

This facility is equipped for measurement of physical and mechanical properties of textiles and metals. Tests performed include: tension, compression, flammability, color and gloss. Environmental chambers are available for fungus, salt fog, rain, freezing rain, sand and dust, wind-dynamic load and solar testing.

TEST FACILITY: Remote Sensor Test Facility	FACILITY NO. 18
FACILITY LOCATION: Fort Huachuca, AZ	ORGANIZATION: Electronic Proving Ground Materiel Testing Division STEEP-MT-ES
TELEPHONE: AUTOVON 879-6074 (602) 538-6074	

This analog data acquisition and recording system covers a variety of transducers, signal conditioning instruments and recording equipment which are used to monitor a wide range of target and background signals characteristics. Transducers include 3-axis and single-axis geophones, fluxgate, variable-mu and proton precession magnetometers and a range of acoustic sensors.

TEST FACILITY: Image Interpretation Facility	FACILITY NO. 19

FACILITY LOCATION: Fort Huachuca, AZ	ORGANIZATION: Electronic Proving Ground Materiel Test Division STEEP-MT-ES
TELEPHONE: AUTOVON 879-6157 (602) 538-6157	

This facility is equipped with light tables which support five image interpreters. The light tables are able to handle film with formats up to 9 inches. The digital comparison viewer is an automated photographic interpretation and measuring instrument enabling automated measurements of X-Y coordinates which are displayed in 10 micron increments. The optical system permits comparison of front and rear spool imagery taken by different sensors at different altitudes. There are a variety of viewing modes provided for including: stereo, pseudo-stereo, binocular-monoscopic, 180 degree upright reversion and superimposed viewing.

TEST FACILITY: Infrared-Optical Test Facility	FACILITY NO. 20
FACILITY LOCATION: Fort Huachuca, AZ TELEPHONE: AUTOVON 879-9157 (602) 538-9157	ORGANIZATION: Electronic Proving Ground Materiel Testing Division STEEP-MT-ES

This facility is used to test the following: ground and airborne photographic, infrared, laser and television sensors, audio visual, drone systems and fiber optics. The facility includes a clean room which is an enclosed structure internal to the building and is temperature and humidity controlled. Clean room contamination is monitored and kept to less than 100,000 particles per cubic foot of air (0.5 micron size). Capabilities include precise measurements of optical component characteristics such as resolution, focal length distortion, astigmatism, curvature of field and aberrations. Other measurements include interferometer measurements, optical film densities and dynamic (frequency dependent) performance characteristics of lenses. Laboratory equipment contained in the clean room is: optical bench, infrared spectrophotometer, interferometer, microdensitometer, camera calibrator, modulation transfer function test system and vibration damped optical test bed.

TEST FACILITY: USA Tropic Test Center (USATTC)	FACILITY NO. 21
FACILITY LOCATION: Fort Clayton, Panama	ORGANIZATION: USA Tropic Test Center (USATTC) STETC-MTD-O
TELEPHONE: AUTOVON 285-5412/5912 011-507-85-5412	

USATTC plans and conducts tropic environmental phases of development tests on a wide variety of Army systems. Among its activities are tropical expossure testing of camouflaged vehicles, electric power generators and fabrics.

TEST FACILITY: Guidance and Control Facility		FACILITY NO. 22
FACILITY LOCATION: White Sands Missile Range, NM	ORGANIZATION: USA Materiel Test and Evaluation Directorate STEWS-TE-AM	
TELEPHONE: AUTOVON 258-1875 (915) 678-1875		

This facility is used to perform rate table, optical and mechanical alignment, fuze, infrared and R-F countermeasure tests and target infrared energy measurements on missile guidance systems; detection systems, launch (and aiming) systems; and target acquisition systems. In the missile launch area, both missile and target IR signatures are measured and correlated with Radar Flight Instrumentation, range timing and camera data. In the laboratory area, rate tables and climatic, countermeasure, R-F infrared laser environments are used and/or applied to test missile guidance packages.

TEST FACILITY: HDL Magnetic Signature Facility	FACILITY NO. 23
FACILITY LOCATION: Adelphi, MD	ORGANIZATION: USA Harry Diamond Laboratories Simulation Technology Branch SLCHD-NW-RI
TELEPHONE: AUTOVON 290-2290 (202) 394-2290	

The HDL Magnetic Signature Facility consists of two independent systems, the Magnetic Latitude Simulator (which can modify the ambient geomagnetic field at APG, simulating the geomagnetic field of any point on Earth or producing a zero field environment) and the Automated Magnetic Data Acquisition System (that measures, digitizes and records 21 simultaneous close-in, under-the-vehicle magnetic signatures). (Note: This facility is located at Aberdeen Proving Ground, MD.)

TEST FACILITY: UV-Visible-Near IR Spectrophotometer	**FACILITY NO.** 24
FACILITY LOCATION: Fort Belvoir, VA **TELEPHONE:** AUTOVON 354-6771 (703) 664-6771	**ORGANIZATION:** USA Belvoir RD&E Center Test and Simulation Function STRBE-JDR

This instrument measures transmittance and total hemispherical reflectance over the 250 to 2500 nanometer region.

Performance Characteristics

Wavelengths Measured

UV-Visual	185- 750 nanometer
IR	750-3500 nanometer

Accuracy of Measurements

UV-Visual	.2 nanometer
IR	.4 nanometer

TEST FACILITY: Dual Band Thermal Imaging System	FACILITY NO. 25

FACILITY LOCATION: Fort Belvoir, VA	ORGANIZATION: USA Belvoir RD&E Center Test and Simulation Function STRBE-JDR
TELEPHONE: AUTOVON 354-6771 (703) 664-6771	

This system consists of a thermal infrared scanner and data storage/analysis hardware and software. The primary instrument is a real time imaging radiometer which operates concurrently in the 3 to 5 micron and 8 to 12 micron bands. The software includes a library of programs to perform a variety of image analysis tasks such as determining the temperature of a hot spot or plotting the temperature histogram of an image.

TEST FACILITY: Spectral Signature Facility		FACILITY NO. 26
FACILITY LOCATION: Fort Belvoir, VA	**ORGANIZATION:** USA Belvoir RD&E Center Test and Simulation Function STRBE-JDR	
TELEPHONE: AUTOVON 354-6771 (703) 664-6771		

This test facility is comprised of an aggregate of spectral signature and measurement equipment spanning the electromagnetic spectrum. The facility consists of fixed and portable equipment which provide the spectral characteristics of material, targets and background. Included are: a radar cross section measuring device (macroscope), IR line scanner, visual and IR spectrophotometers, lasers, telephotometer and assorted display and instrumentation equipment. The focus of the facility is obtaining characteristic multi-spectral signature data of military targets for purposes of camouflage and suppression.

TEST FACILITY: Radar Cross Section Measurements	FACILITY NO. 27
FACILITY LOCATION: Fort Belvoir, VA TELEPHONE: AUTOVON 354-6771 (703) 664-6771	ORGANIZATION: USA Belvoir RD&E Center Test and Simulation Function STRBE-JDR

This equipment is able to make radar cross section measurements of scale models employing the principle of frequency scaling. It utilizes a basic frequency of 100 GHz and a resolution of .5 inch in the imaging mode. For example, a 1/10 scale model of a target is employed to obtain cross section and imaging data directly corresponding to a full-scale target at X-band (approximately 10 GHz).

TEST FACILITY: FTIR Spectrometer	FACILITY NO. 28

FACILITY LOCATION: Fort Belvoir, VA	ORGANIZATION: USA Belvoir RD&E Center Test and Simulation Function STRBE-JDR
TELEPHONE: AUTOVON 354-6771 (703) 664-6771	

This Fourier Transform Spectrometer measures transmittance, diffuse reflectance, specular reflectance and internal reflectance over the region of 2 to 20 microns. It is capable of providing high resolution, high signal/noise spectra on high opaque and low reflectance samples in less than five minutes.

TEST FACILITY: Computer-Aided Radar Test Facility	FACILITY NO. 29
FACILITY LOCATION: Fort Belvoir, VA TELEPHONE: AUTOVON 354-6771 (703) 664-6771	ORGANIZATION: USA Belvoir RD&E Center Test and Simulation Function STRBE-JDR

The horizontal reflectivity arch is an indoor radar test facility designed to perform radar cross section measurements, radar cross section reduction (RCSR) measurements, radar absorber evaluations, antenna pattern measurements, free space radar transmission measurements, microwave target imaging, and measurements of radar material absorber properties, i.e., complex permittivity and permeability. These measurements can be performed in the radar frequency range of 2-18.4 GHz in a continuous wave mode. This computer controlled facility can be used to measure both monostatic and bistatic return from a target. The arch is capable of performing direct radar transmission measurements through cloth materials used for camouflage nets and therefore can serve to evaluate new net materials as they are produced by the manufacturer. To evaluate new radar cross section reduction concepts, for example radar absorbing paints or radar absorbing structures (RAS), the radar arch system can perform near far-field measurements for up to 14 inch square panel which have been coated with the radar absorbing material. The radar absorbing characteristics of the material is then established in the 2-18.4 GHz range. These frequency bands are the primary surveillance bands in military radar systems. By using this arch with Ft. Belvoir's 100 GHz RCS scaling facility, RCSR characteristics at mmW frequencies are also obtained.

TEST FACILITY: Textile Engineering Laboratory	FACILITY NO. 30

FACILITY LOCATION: Natick, MA TELEPHONE: AUTOVON 256-4351 (617) 651-4351	ORGANIZATION: USA Natick RD&E Center Engineering Program Management Directorate STRNC-EPT

This is a completely equipped facility for textile engineering analysis in areas of functional performance important to the military. A complete range of equipment is available for evaluating the stress-strain properties of textiles in tension, compression, flex, torsion and impact. Tests can be performed on camouflaged textile items (e.g., clothing, nets, screens and shelters).

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APPENDIX D

INTERACTION PROCESSES

D-1 INTRODUCTION

The purpose of this appendix is to describe the capabilities and trends of reconnaissance, surveillance and target acquisition (RSTA) sensors to interact among themselves and with various kinds of targets. The trends in both RSTA and camouflage development are strongly technology dependent. Development efforts to increase combat effectiveness, operational survivability, flexibility and threat responsiveness indicate directions for the future of RSTA versus camouflage interactions.

These interaction processes make increasing use of sophisticated techniques involving both mature and emerging technologies and applications such as the following:

- New materials (composites, advanced detectors, cryogenics, molecular synthesis products, energy sources).
- Microprocessors (very high speed integrated circuits (VHSIC), very large scale integrated circuits (VLSIC), parallel processing, micron/submicron technology).
- Millimeter Wave/Microwave Integrated Circuits (MMICs, gyrotrons, quasi-optics).
- Signal processors (algorithm development, imaging, polarization, state-vector, fine structure signatures, digital signal integration).
- IR arrays (scanning, imaging, agile multi-color).
- Integrated optics/optical processors (fiber optics, photonic transducers, 3-D integration).
- Automation and robotics (adaptive sensing, artificial intelligence, navigation, adaptive control, communications).

Camouflage concepts (particularly dynamic or adaptive camouflage) can utilize advances in the technology base to achieve improved capabilities. Improved products and processes and the applied science underlying technology advancements need to be directed toward practical applications and the systematic use of scientific knowledge to produce useful materials, systems, methods and devices and to design and develop camouflage products and process prototypes.

The following paragraphs address interaction processes in the camouflage versus RSTA competition that may be significant for future camouflage/concealment/deception (CCD) systems and techniques. Interactions processes considered include:

- Visual observation
- Electro-optics systems
- Infrared systems
- Radar systems
- Millimeter wave (MMW) systems
- Target signature modulation and synthesis
- Intelligent sensors and multi-sensors (mixed, multi-mode)
- Sensor fusion capabilities
- Distributed intelligence capabilities
- Advanced signal processing
- Multimode logic
- Discriminant logic (adaptive algorithms)
- Signature fire structure exploitation (fake target synthesis)
- Enhanced command, control, communications and intelligence (C^3I) and networking

D-2 VISUAL OBSERVATION

Advancing the state-of-the-art in visual observation will exploit the technologies in photo cathodes, fiber optics, multi-stage image converters and microchannel electron multiplier plate developments. The image intensification devices emerging from these technologies are expected to upgrade significantly the visual RSTA capabilities at all levels of threat. Sensors falling in this category include weapon sights, night vision aids, periscopes and binoculars. Long-range viewers with high sensitivity photo cathodes using III-V detector materials for extended IR viewing use pulse-gated techniques to observe laser (1.06 mm) illuminated targets out to 3+ km.

As image intensifier capabilities improve, they are likely to replace the easily detectable active IR on combat vehicles in forward areas. The fabrication technology to produce large II wafers for III-V photo cathodes in next generation devices is available worldwide. These devices will provide starlight capabilities for active combat vehicles.

Whether ground or air visual aids are used, future developments will depend on real-time imaging as in HUDs, on computer-based digital processing of target and cuing information and on overcoming the challenges of extremely noisy backgrounds and highly variable, frequency-dependent responses of targets and backgrounds. In addition, there are transmission losses through the atmosphere by absorption, scattering, and turbulence, and a variety of geometric and environmental conditions to be considered. Finally, there are the requirements for imaging to perform the detection, recognition, identification, and acquisition functions.

How the human observer "sees" the target scene depends on the sensor imaging processes he employs to perform his task. All visual systems convey information and the form and performance of the imaging devices, including the eye/brain of the observer, are related to the nature of the target scene, radiance, luminance, contrast, spectral composition, the task being performed, and the time available to perform it.

If the observer is viewing the tactical scene directly, or even if there is an intervening sensor such as an image intensifier, IR scanner, microwave device, or camera lens/film, the eye/brain combination itself is the final detector, processor, and imager. Processes of the human eye/brain combination through which the observer perceives objects in the scene and draws conclusions about them are not well understood. Continuing psychophysical and psychological investigations will improve this understanding to the point where target signatures can be wholly quantified for the widely variable conditions and tactical needs of the viewing situations.

Within the detectable waveband of the normal human eye (0.35 to 0.7 μm) and its minimum angular resolution (≈1 minute of arc), the eye proceeds to search the visible scene for discernible and recognizable objects. The character of the target objects, the surrounding background, and conditions of the environment, as well as the training and prebriefing of the observer all affect the outcome. Among the parameters that may affect the visual detection, recognition and identification of the target objects in the scene are those previously identified:

- Size/shape/shadow of the target and background.
- Color/hue/texture of the target and background.
- Movement (and changing contrasts) of the target or observer.
- Terrain contour and line of sight.
- Scene illuminance (absolute value of light level).
- Reflectance of target and background (fraction of light reflected and the distribution between the diffuse and specular reflection components).
- Range from observer to target/background.
- Atmospheric absorption, scattering, and refraction along the visual path (including weather effects).

Some of the above parameters, such as size and shape, represent inherent target characteristics and, therefore, in describing target signature, are measured and quantified. There remain the important tasks of determining human eye response to the other parameters that influence scale, contrast, and acutance, as well as the time to observe and to decide what task is to be performed in the tactical situation in question. For camouflage assessment, the target signature and its many parametric variables represent only a few steps along the path to quantitative determination of camouflage requirements.

Extensive investigations of visual search behavior leading to target acquisition have been undertaken by many investigators. Approaches to the visual search problem have pointed out that tactical targets typically occur in somewhat "cluttered" surroundings thus complicating the detection problem. Whether the detection is made by direct visual search of the terrain or indirectly through use of a sensor/display system, the observer must somehow reject the clutter and detect the right object. Quantitative prediction of the effects of clutter or confusing objects on the search and detection process has proven to be difficult. Some investigations have concluded that

visual search behavior is characterized by brief glimpses of the terrain separated by rapid eye movements or saccades. The likelihood of looking at a target with any particular glimpse is, in most models of search behavior, assumed to result from either random motion or a mechanically systematic search pattern. It may be assumed that the observer uses extra-foveal vision to evaluate the terrain before each saccade (or look) to maximize the likelihood of seeing the target. Quantitative data on extra-foveal search have shown that such behavior is lawful and predictable. Observed results can be applied to dynamic air-to-ground search yielding target acquisition predictions which compare favorably with those obtained by other methods. For example, one study suggested a "glimpse model" that yields a cumulative probability of target detection as a function of decreasing range as an observer approaches the target area:

$$P_{cum}(x_k) = 1 - \prod_{j=k}^{N} 1 - P_L(j)P_R(j)$$

where

x	=	horizontal distance from observer to target along the ground track
P_L	=	probability of looking at (with foveal vision) the target
P_R	=	probability of resolving (seeing well enough to recognize) the target
k	=	an integer such that $x_k \geq$ the minimum visual range, as established by field-of-view limitations
N	=	an integer such that $x_N \leq$ the maximum visual range, beyond which detection is impossible.

The model, as expressed, will yield a curve of cumulative probability as a function of range for any set of target, background, viewing, (flight) geometry, atmospheric, and observer parameters. The compute curve can then be compared directly with the results obtained in the field or in a simulation, provided all the necessary parameters can be determined.

Models of the visual acquisition process for random search situations have been developed based on the physical properties of the eye.

The physical properties of the eye lens and retina together with the involuntary eye movements (tremor and drift) are considered to be the basic factors defining single-glimpse detection probability. Coupling of data concerning these factors with simple probability theories of information transmission from eye to brain via neural networks has allowed accurate prediction of several sets of basic laboratory threshold data.

Introduction of the concept of convolution of object profiles with the spread function of the eye lens allows extension of such single glimpse predictions to indistinct objects. The effects of atmospheric attenuation and range dependence of subtended size may also be introduced at this stage. Using this comprehensive formula for single glimpse probability as an input, a cumulative search probability model has been developed for random search which takes into account search field-of-view, visual lobe effects, and the transition from single to multiple glimpse situations at any part of the field-of-view.

In one series of field tests of direct visual air-to-ground target acquisition, the content of the data used to assess the visual tasks tends to show what is important with regard to visual target signatures. Characteristics of the target with respect to size, shape, motion, orientation, color, reflectivity, and contrast are the elements of target signature that must be measured in analyzing visual processes. The background-type reflectivities, colors, illumination of the scene, and various cues also must be measured. In this evaluation, not only the psychophysical aspects, but the tactical aspects of visual target acquisition were recognized. The type or level of target acquisition performed in the tests were classified under four tasks:

(1) Detection: The process of isolating an object of interest from the background (e.g., "I see something that might be what I am looking for"); operationally defined detection occurs when the observer commits himself to further inspect a particular object in his field of view.

(2) Recognition: Consists of perceiving specific object features in sufficient detail to assign the object detected to a class of things (e.g., "the object is a vehicle").

(3) Identification: Consists of perceiving object features in sufficient detail to assign the object to a specific subset of the class of objects (e.g., "what I see is a tank").

(4) Classification: An extension of the identification process in which the observer is asked to make further decisions about details of the target (e.g., "the object is an M48 tank").

In all the preceding studies, the specific measures employed in the visual processes involve parameters such as target size and contrast, contrasting detail in the target, and the complexity of the background*. These have predictive importance for specific target/background combinations. Among real-world objects, one would expect to find unique patters, textures, luminances, irregularities, and other particular qualities that are most important to the prediction of an observer performance. To adequately predict observer performance, particularly at the recognition level, merely to know the target object size and contrast (overall luminance contrast) is insufficient. Visual camouflage evaluation, particularly at the recognition and identification levels, must take into account such variables as target detail size and luminance, the detail contrast within the target, and background complexity and ambiguity as well as overall target size and contrast.

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* Complexity of the background: the degree of clutter or confusing objects such as trees, grass, rocks, etc., and their brightness, composition, shadows, and internal details.

D-3 ELECTRO-OPTICS SYSTEMS

Electro-optics systems of a passive or low-detectibility nature including image intensifiers, TV sensors and focal plane arrays are beginning to outnumber the active systems such as FLIR and laser illuminators on the battlefield. Passive means can be used in RSTA from aircraft, helicopters, RPV's and satellites, especially prior to hostilities because they can operate covertly and continuously without compromising their presence.

The passive image intensifiers and TV/LLLTV (low-light-level TV) systems rely primarily on human observers to view and interpret their output displays of target features/signatures. The visual signatures presented in tactical scenes containing the target object(s) and background(s) are characterized by size/shape/shadow of the target and other objects including their edges, lines, contours and physical aspects. To this is added their color/hue/texture, movement (if any) and the brightness and contrast of the target and other objects presented to the observer. Camouflage must mimic the natural surroundings in the observed spectral range and the patterns, textures and color effects, both close up and at a distance.

The human, having been pre-briefed in some way and given a task (e.g., "find the tank(s)"), performs a visual image scan. What the human sees or perceives in the scene will depend on temperatures (objects, ambient), reflectance/luminance (including specular "glints" and highlights), inherent/apparent contrasts, spatial frequencies (including gray shades, background complexities and unique patterns) and any cues about the target object (including effluents, dust, tracks, functional cues such as firing phenomena and deployment geometry).

The observer now has the electro-optics sensor to assist him in making observations of the target scene. He may control the field of view, brightness, contrast, scene illumination, viewing aspect, range-to-target, observation time and other conditions of observation. The brightness may be made many thousands of times greater, the field-of-view (FOV) narrowed to a fraction of the target or the viewing aspect shifted to observe any contrast differences as desired. Any of these controls may improve the conditions sufficiently to allow the viewer to decide on detection or recognition or identification. It is important here to note that, beyond the quality and content of the imagery, one also needs to know what level of information must be extracted to make the required decisions. In some cases, it may be necessary only to determine whether military targets are present in a given area and, indeed, the images may be too poor to yield additional information. Camouflage may be effective in assuring such poor images. In other cases, it may be necessary to recognize the targets as vehicles, weapons, fortifications, command centers or supply points or other classes of targets. In still other situations, it may be necessary to identify vehicular targets as specific vehicles types (e.g., tanks, trucks, engineer equipment, etc.). In any case, the interpretability of the image of the tactical scene is a factor in camouflage effectiveness.

Passive focal plane arrays and IR real-time imagery systems operate in all regions of the IR spectrum from thermal IR (0.7 μ - 1.6 μ), mid-IR (3 μ - 5 μ) to far-IR (8 μ - 14 μ and beyond). These sensors may be combined with non-IR optical sensors and day/night weapon sights to provide high-resolution RSTA information. Use of these devices in head-up displays (HUDs) increases the accuracy and effectiveness

of camouflage penetration. Combined TV/IR systems of these types on manned/unmanned airborne platforms has raised the RSTA multimode/multisensor capabilities to new levels of performance against tactical targets. Linked to microprocessors, IR array systems may be feasible utilizing on the order of 10^6 separate sensors and real-time dissemination of displayed information to large numbers of dispersed observers/data stores simultaneously.

Target signature analyses by the RSTA systems which camouflage must neutralize in the future will employ sensor technology integration that permits shared antennas, optics, housings, detectors, signal processors, controls and displays. Multisensor integration over diverse spectral bands and operating rates with central processors as well as distributed microprocessors built into individual sensors will improve performance, reliability and survivability of the RSTA systems.

D-4 INFRARED SYSTEMS

Infrared targets include natural backgrounds such as water, forests, and grass as well as man-made targets such as roads, structures, vehicles, and personnel and their equipage. Most ground targets are opaque or nearly so and are reasonably close to ambient temperatures (i.e., 300°K). Some targets are distinguished by passive IR sensors because they have higher temperatures than their surroundings. Typical of such targets are vehicles and their exhaust manifolds, power units, and similar heat energy sources which present bright targets in the thermal IR spectrum. Identification of passive targets which are near ambient temperature requires recognition of characteristics such as size, shape, orientation, or contrast. For active IR sensors such as laser scanners, targets are distinguished by theer spatial and polarization characteristics of the reflected IR energy. Differences in the specular and diffuse reflectance properties of target surfaces produce significant differences in the spatial distribution and polarization characteristics of the reflectant energy in the various target aspects.

A major problem for imaging sensors is to define the target rapidly enough in a cluttered background. The spatial characteristics of the imaged target when contrast and resolution are sufficient provide the principal target signature quality for the observer. Spatial characteristics of the imagery are similar in the visible and passive thermal IR portions of the spectrum and hence are generally readily interpretable. In addition, the thermal IR carries information about the spectral emittance. In the near-IR reflective spectrum, the spectral characteristics of the radiation convey information about the "color" of targets and backgrounds and some targets may be distinguished on this basis. Multispectral sensing and discrimination is being applied to aid the RSTA observer in this area.

Thermal IR in its spectral emittance function observes dissipation of heat from a vehicle engine or motor generator (e.g., a "hotspot"). Perhaps even more interesting for IR target discrimination is the apparent behavior of certain painted surfaces at thermal IR wavelengths. The surface properties of certain materials (e.g., olive drab painted surfaces) show much greater specularity in the IR wavebands than the natural surroundings and surface properties of the target may be revealed by sensing the polarization content in the thermal emission and the "glint" in 10.6 μm imagery.

Coherent illumination introduces still other variations in target signatures. The return from a complex target such as a combat vehicle illuminated by a coherent source can be quite variable. For example, the source may focus on only a small part of the target. Under these conditions, target signature depends upon what portion of the target is illuminated, whether that portion of the target is visible to the receiver, and whether secondary reflections to other parts of the target or the near surround become primary reflection sources.

The state-of-the-art in IR sensing, imaging and image enhancement is undergoing rapid development. The basic target attributes of reflectance and emittance are being interpreted in increasingly greater detail in terms of specular response, spectral response, and spatial response of the targets and backgrounds. In this Guide, it is only possible to touch upon some of the many aspects of IR signatures and to present examples that may be of interest for camouflage.

Four principal sources of IR energy are solar heating, combustion of fuel, friction and thermal reflection. Ground targets present a mixed variety of these IR radiations to RSTA sensors and observers.

Solar heating effects are confined mostly to the exterior surfaces of the targets. This type of heating highlights the target outline and overall shape of the external features. The outline of these features can provide helpful recognition cues. Shape cues are usually similar to the overall visible appearance of the target. For example, the solar-heated M113 APC appears box-like with a sloping front; a solar-heated M60 tank appears as a small oval shape atop a larger oval shape. These shape cues are recognizable out to medium and long ranges, depending on the IR sensor resolution. Since the sides have more defined contours, the side view shapes are generally easier to recognize than the front views. Unfortunately, solar heating as a source for these cues is highly variable and solar-heated features as IR recognition cues are somewhat unreliable due to variance introduced by surface reflections, weather, atmospheric factors, and solar heating changes during the course of the day. In addition to atmospheric variables and surface reflections, solar heating rates are also affected by the object's ability to absorb sunlight. Generally, dark-colored objects are better absorbers of IR than the light (white) objects.

Fuel combustion heat originates in operating engines. The heat is conducted to the surfaces of the surrounding engine compartment. Engine compartment temperatures can exceed 200°F. The surfaces of these compartments radiate highly visible features that can be detected by IR sensors and provide very reliable cues. Personnel heaters usually operate by tapping engine heat and piping it into personnel spaces within a vehicle. After some time, the heated personnel space becomes visible in the infrared. Likewise, engine muffler and exhaust pipe temperatures are quite high and provide good cues. The engine, heated compartments, and exhaust features themselves may not be highly defined on the IR display. These features are very hot and easily detected at very long ranges.

Frictional heat is produced by the moving parts of equipment and vehicles. This heat is less intense than the high temperatures resulting from the engine combustion. Frictional heat is generated only when some parts of the equipment or vehicle is in motion. Frictional heating generates sufficient temperatures to provide long range IR signatures. However, these features usually appear at medium intensity in the thermal sensor. The transport systems are the sources of most frictional cues. The tracks,

roadwheels, drive sprockets, support rollers, and shock absorbers are the frictionally heated features on tracked vehicles. Wheeled vehicles generate frictional heat in the tires, shock absorbers, drive shafts, transmissions, axles, and differentials. The smallest of these features can be resolved at long ranges only if they are quite warm. The tires, shock absorbers, and differentials are good medium-to-long-range detection and recognition cues. Frictionally heated feature cues can be used at long range to detect the vehicle and classify it as wheeled or tracked. At medium range to short range, these cues can be used to identify the vehicle.

Certain smooth or glossy surfaces such as vehicle windshields and glossy painted fenders can reflect IR radiation images impinging on them from many sources. Vehicle windshields, such as those of the trucks, often appear very dark because they reflect the low radiant temperatures of the cold sky. Similarly, the fenders of a tank can appear very dark due to this thermal reflectance of the cold sky. An overcase sky can cause warmer thermal reflections. The thermal radiance from a fire located next to a glossy painted APC could be reflected off the vehicle's flat side surfaces. Thermal reflections can produce some odd signature effects. The thermal sensor user should be aware of this phenomenon, but not overly concerned. Only very smooth glossy surfaces are subject to strong reflections. Generally, surface reflections are diffuse in nature and do not cause bright display images.

The daily diurnal heating and cooling cycle caused by the daily solar heating of the earth's surface induces continual temperature changes to natural and man-made objects. Natural background objects such as trees, bushes, grass, rocks and earth are heated passively through absorption of solar energy beginning at sunrise. In the afternoon, as the sun declines, these begin to cool. After sunset, objects otherwise undisturbed cool down to approach the ambient air temperature. Thus, the IR background is thermally dynamic and may be quite noisy for sensors depending on contrast measurement.

Individual objects and targets heat and cool at different rates. Their degree of IR radiance or reflectance may vary rapidly depending on their thermal state, mass and other conditions. Sometimes, the radiated temperature of target objects reaches the temperature of the surrounding background resulting in a thermal contrast of zero (T = 0°). Most IR sensors do not resolve temperature differences of less than 1°F, but advanced IR systems can be expected to resolve 0.1°F or less.

Normally, in sunny-day cycles, the target does not reach the nighttime background temperatures before the sun rises once again to restore the heat cycle. As the sun rises, the cool background warms up rapidly to exceed the target temperature. This point where the background temperature passes the target temperature is called diurnal "crossover." This is illustrated in Figure D-1 at 0700 hours and again at 1530 hours. When the morning crossover occurs, the IR sensor can display the background as brighter than the target and a negative contrast target appears. When the afternoon crossover occurs, the target appears brighter tahn the background for a positive contrast target. The timing of these crossovers is greatly influenced by environmental factors. Thus, this discussion must be thought of as only a generalization of the "diurnal" and "crossover" phenomena. Nevertheless, the camouflage possibilities for blending and disguising tactical targets are evident.

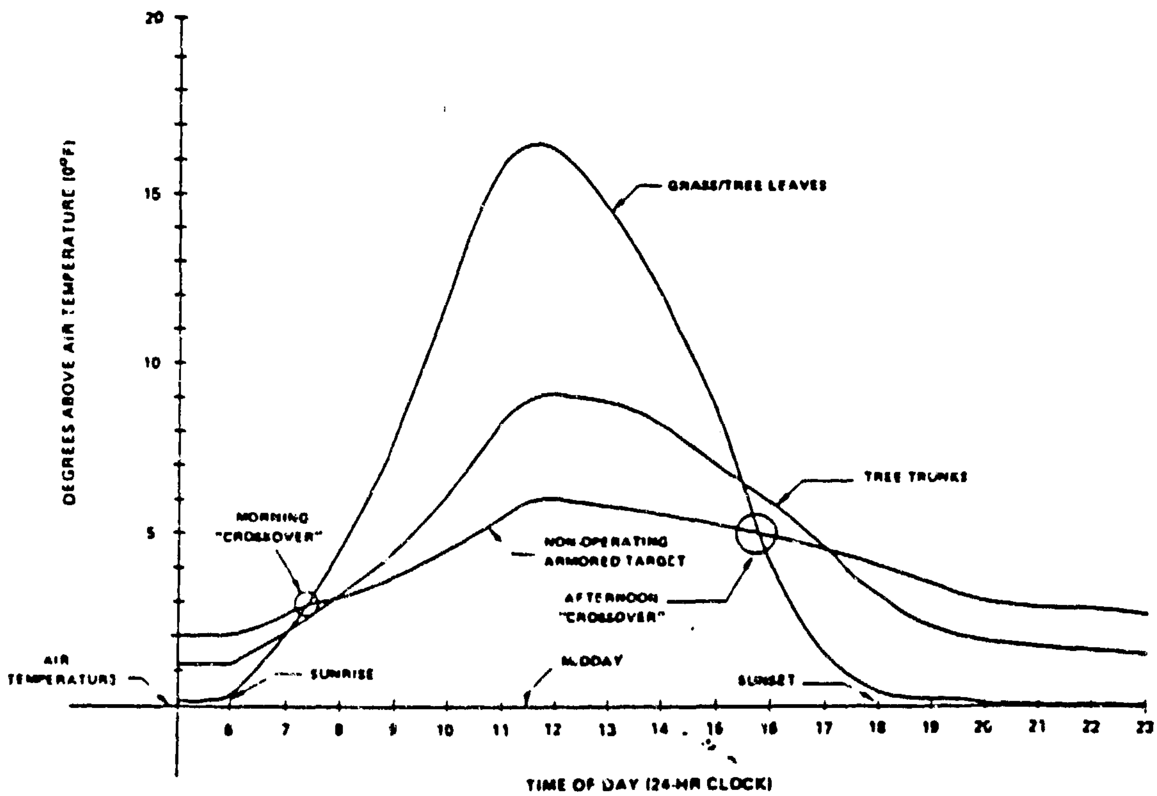

Figure D-1. Diurnal Cycle - Heating and Cooling Cycle for Solar Heating of Background Objects and Non-Operating Targets.

This reflectance or backscatter for active IR systems is governed by target/background material electrical properties including dielectric, and surface scattering/interference solid state properties that are quite complex. Active IR sensors make use of the spectral transmitted beam in either a phase modulated or range-gated form. In the spectral modulation case, a frequency modulated signal is placed on an optical carrier beam. Very accurate target range and surface penetration depth information can be obtained by detecting phase front distortions in the return beam induced by the target/background objects. In the range-gated form, the two-way propagation time is measured to obtain a precise distance to the target (iie., laser rangefinder).

For these active systems, several performance factors are of interest for camouflage. First, the reflected target object energy must be high enough to produce an acceptable signal-to-noise ratio (i.e., detection). Beam dispersion often limits the operational distance here. Second, the beam pattern may be too large in diameter as compared with the target and the phase information becomes ambiguous. For the rangefinder, this causes uncertainty about which part of the beam (target or background) produced the strongest (or first) return. When current technology advances in clutter analysis, material reflectances and weather effects permit, these sensors will enhance RSTA operations and serve as a useful component of multisensor systems.

IR RSTA systems, both active and passive, have proliferated among the armed forces of many nations in the past decade. Prominent among such systems are the day/night sights for RSTA and weapon control and the head-up display equipment for pilots and other vehicle operators. The day/night sights can accommodate EO and IR sensors to perform observation, rangefinding, fire control, and weapon guidance as well as reconnaissance and surveillance data collection. Gyro stabilized units on aerial platforms combine optical viewing with IR imagery using common optics orientations that allow observers to utilize any of several sensor options and/or wavebands against ground targets simultaneously.

RSTA sensors now available worldwide cover visible, near IR, 3-5 micron/8-14 micron wavelengths and are beginning to perform sensor fusion functions along with laser, radar and photo techniques against individual targets and target patterns. In some cases, optical/IR combinations may more than double recognition ranges (e.g., from 2 km to 4 km) against tanks, for example. Some optical/radar and IR/MMW applications are significantly increasing range (out to 5 km or more) and resolution ($<$ 1 mrad) against tactical targets. Techniques of camouflage to reduce target/background contrast and to suppress, filter or modulate unique target signatures must deal with advanced sensor technology for discrimination, fusion, pattern recognition and real-time multisensor, multimode RSTA capabilities.

Lightweight, high resolution IR imagers and line scanners are appearing more frequently now in unmanned vehicle applications. On-board microprocessors are capable of handling very high bit-rate data streams, near real-time signal processing and narrow bandwidth data links that can provide greatly increased and effective RSTA operations, integrated air-space-ground information gathering and discrimination. Combined multisensor systems portend very high quality target detection/recognition and discrimination capabilities which camouflage will find it necessary to neutralize.

D-5 RADAR SYSTEMS

The radar microwave spectrum discussed in this section extends over a wide domain from 0.1 to 35 GHz (approximately 1 m to 1 cm wavelengths). Microwave sources and detection systems of different types are employed according to their efficiency in generating and receiving microwaves in various regions of this spectrum. Radar average power may vary from milliwatts to kilowatts or more depending on the application.

Microwave target signatures are generally described in terms of the continuous wave (CW) radar cross-section (RCS) of a given target object. The RCS is quantitatively measured in the form of the ratio of power density in the vector signal scattered from the target in the direction of the receiver to the power density of the radar wave incident upon the target. The usual experimental definition is given by:

$$\sigma = \frac{(4\Pi)^3 R^4 P_r}{P_t G^2 \ ^2},$$

where

P_t = transmittance power
P_r = receiver power
R = distance from radar antenna to target
= wavelength
G = transmittance (receiver) gain

The radar cross-section, σ, has the dimensions of area (square meters).* However, specification of a single value for σ holds only for a particular target at a particular aspect, the specified polarization combination of the transmitter and receiver, and the wavelength for which the RCS was established. In practical terms, RCS may vary from 10 to 50 dB as these parameters change.

For distributed targets, such as terrain background and other surface features, the differential scattering cross-section (or average scattering cross-section per unit area), σ_0, is used to describe the return from the ground** which consists of a large number of scatterers with independent phases within the illuminated area. The size of the illuminated area (and the total cross section of that area) varies with the radar parameters including beam width, pulse width, wavelength and polarization. For low grazing angles, with precise control of antenna gain with the use of pulse length to limit the forward resolution of cell size and with range resolution to separate returns from different angles, σ_0 can be expressed as:

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* Current work on radar cross-section accepts the square meter as the dimension of area, whereas earlier measurement work used the square foot as the common unit; RCS varies over a wide dynamic range and it is convenient to use the logarithm form "decibels" as reference to one square meter (dBsm), and dBsm = 10 $\log_{10} \sigma$ where σ is in square meters.

** Scattering cross-section per unit projected area normal to the beam and per unit area on the ground are both used by various authors and caution must be exercised to determine which value of σ_0 is being discussed.

$$\sigma_0 = \frac{(4\Pi)^3 R^3 P_r \sin\theta}{P^t G_o{}^2 (\Phi/2) c\tau},$$

where

G_o = antenna gain (assumed constant across the beam, zero elsewhere
Φ = beam width
c = speed of light
τ = pulse length
Θ = angle of incidence (complement of depression angle).

It is normally assumed that σ_o is constant over the illuminated area. At fine resolutions, smooth targets may be only partially illuminated and the above definition of σ_o may not be valid whereas coarser resolutions that include many specular and diffuse scatterers within the beam would be acceptable.

If the resolution element size (P_x, P_y) in projected square meters multiplied by the average scattering cross-section of the illuminated area, σ_o, determines the return signal power from the terrain (clutter), then the signal-to-clutter ratio can be expressed as:

$$S/C = \frac{\sigma}{\sigma_0 (P_x, P_y) \sin},$$

where σ is a discrete target cross section and is the "look-down" or depression angle of the radar. In practice the value of σ_0 fluctuates widely and it has been found that reliable detection of targets can be expected when S/C in decibels has a value of 10-13 dB or more.

Some typical average backscatter cross-sections for terrain features encountered in cluttered environments are listed in Table D-1 for X and K_a band frequencies. These values have been averaged with respect to polarization.

Over the years extensive experimental programs have been conducted to develop reliable measurement data on the reflectivity (RCS) of tactical targets. The reflectivity of a target depends on target size, shape, surface material properties (e.g., conductivity, permittivity, and permeability), radar frequency, target aspect, polarization, the power factors, and the character of the ground plane. All of these variables must be evaluated and controlled if RCS data are to be read and interpreted unambiguously. In the cluttered ground environment, strong returns are obtained from objects in the vicinity of the target (background), from direct backscatter (foreground) and from target-scattered background (forward illumination off the target) unless short-pulsed range gating, high-resolution and coherent processing are used to exclude these unwanted reflections. Application of conical scan demodulation for spatial features discrimination and high resolution techniques using doppler processing and beam shaping can vastly improve modern radar performance. Statistical categorization of clutter is also helpful.

Table D-1. Typical Average Backscatter Cross-Section Characteristics of Terrain Features.

Features	Averaged Cross Section, dBsm	
	Ka	X
Asphalt road	-17	-26
Gravel road	-13	-23
Concrete road	-22	-30
Disked field	-15	-22
2-in. grass	-17	-23
3-ft. soybeans	-12	-17
Desert sand	-22	-26
Open woods	-19	-23
Wooded hills	-19	-25
Suburban areas	-10	-13
Cities	- 5	- 7
Smooth water	-25	-30
Snow	-17	-21
Forests	-12	-15

Ref: Comprehensive Target Signature Measurement Program, 2nd Interim Technical Report Vol. I, Univ. of Michigan, June 1966

Fine resolution of some present and future high-performance radars along with advanced digital processing offers the capability of isolating and coherently analyzing the many individual scattering centers on a target to perform target recognition. The complexity of typical tactical targets, substantially complicates the task and data on such targets are always in short supply. Measurement and analysis of target perceptibility in situ requires: (1) measurement of the targets' free space RCS, (2) measurement of the background clutter, and (3) combining these results in valid signal-to-clutter models. Measured and calibrated RCS data of this kind can suggest camouflage concepts and opportunities. Past measurements on many different tactical targets are often lacking essential ground truth and, because such a large number of variables must be accounted for, the RCS data available for some ground targets may be quite inconsistent and difficult to correlate. Controlled test measurements are often required. (The Hostile Weapons Location System [HOWLS] program, for example, under DARPA, examined the RCS, signal-to-clutter and other characteristics of artillery targets by measurement and analysis of these targets in controlled experiments and such work is indicative of requirements useful for camouflage development.)

Typical backscatter RCS for a tank using an X-band radar with parallel HH polarization (transmit horizontal - receive horizontal) shown in the polar diagram in Figure D-2 illustrates a characteristic lobe pattern often observed for large tracked vehicles. The strong narrow lobes correspond to the major dimensional presentations of the tank at forward, rear, and broadside aspects. From the same data source the RCS values for linear and cross-polarizations at several aspect angles viewing the target horizontally are given in Table D-2. The mean value of all values shown is

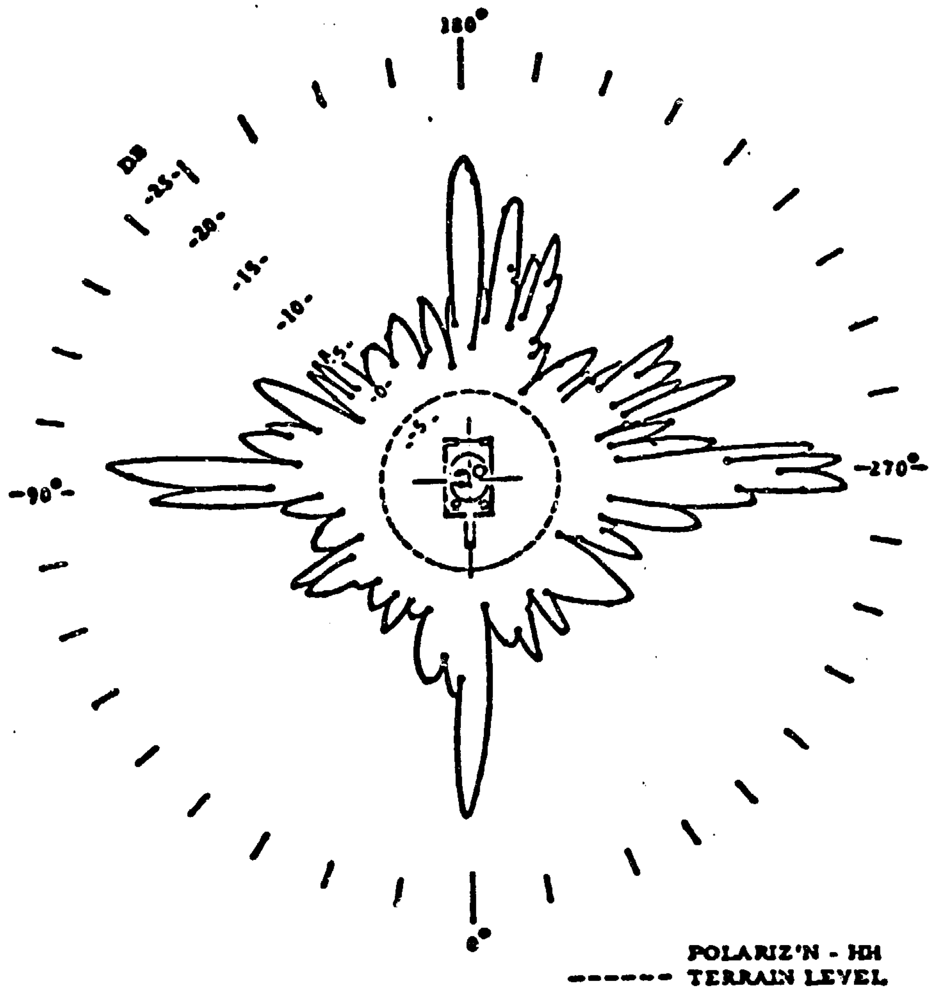

Figure D-2. Typical Backscattering Cross-Section Polar Diagram of a Tank at X-Band.

Table D-2. Radar Cross-Section of a Tank at X-Band.

Polarization		Cross Section					
		3 1/2 Off Broadside		Head-on		45 Head-on	
		dBsm	m^2	dBsm	m^2	dBsm	m^2
σ_{HH}	σ	23.4	220	22.7	187	18.9	78
	σ_{max}	30.1	1000	25.7	370	22.8	190
	σ_{min}	19.1	81	13.7	26	17.0	50
σ_{VV}	σ	18.8	74	18.7	74	17.0	50
	σ_{max}	25.3	340	20.8	120	15.1	32
	σ_{min}	15.2	33	17.8	60	13.7	24
σ_{HV}	σ	13.0	20	5.8	3.8	8.0	6.3
	σ_{max}	16.3	43	7.6	5.8	10.2	10.5
	σ_{min}	8.9	7.8	4.3	2.7	4.7	3.0
σ_{VH}	σ	12.0	16	7.4	5.5	9.3	8.5
	σ_{max}	13.8	24	9.3	8.5	10.9	12.0
	σ_{min}	10.5	11	5.7	3.8	8.0	6.3

Ref: Comprehensive Target Signature Measurement Program, 2nd Interim Technical Report, University of Michigan, June 1966.

determined to be 312 m^2. If the target were viewed from greater elevation angles (e.g., from an aircraft), the RCS values would decrease on average perhaps to one-half of the values shown. At longer wavelengths such as VHF/UHF the RCS decreases as illustrated in Figure D-3. The typical lobe pattern is still in evidence peaking on either side of the normal 0° azimuth angle (in this case, broadside). The cross-section envelope here shows larger RCS than one would expect for this type of target at VHF but is not unusual. The longer wavelengths do not see the finer dimensional detail on the vehicle but respond to the larger flat plate surfaces and the longer contours of the vehicle shape. Such radar performance might be typical of older RSTA systems encountered many places in the world. For example, Table D-3 illustrates a range of RCS values at L- and X-band for two classes of vehicles: jeeps and 2-1/2-ton trucks. The data represent a mix of aspect angles and slight vehicle differences under roughly similar measurement conditions. The large truck cross-sections are typical of targets with large relatively flat surfaces and many scattering corners and edges.

Larger tactical targets may in some cases exceed the size of a single resolution cell and hence cannot be strictly considered as point targets. Table D-4 lists the median X-band cross-section of several military vehicles measured at low grazing angles with horizontal polarization. The wide variation among the data is attributable to differences in the measurement conditions, the terrain variability affecting ground clutter, and differences in the depression angles employed. It should be noted, however, that these differences are among those that would be expected to occur in the real tactical environment and, hence, the variability in the perceptibility of military vehicles involves real uncertainties.

In conjunction with the development of microwave attenuation materials for signature suppression, radar cross section of an M113 armored personnel carrier at X-band were measured at the U. S. Army Electronic Proving Ground, Fort Huachuca, Arizona. The measurement of RCS employed a modified test radar with a depression angle of approximately 20 , simulating airborne surveillance systems. The measured cross-section of the M113 as a function of azimuth angle is shown in Figure D-4. The large broadside RCS of 10,000 m^2 (40 dB) was observed over a very narrow angular width, i.e., 1/2 in azimuth. The front and back RCS's are likewise sensitive to azimuth. From a practical point of view, the large broadside flash from targets like the M113 may be of marginal significance because of the small angular extent and the median RCS at all other aspect angles ranging from 1 to 6 m^2 is obviously the most likely. The average RCS in this case is well below the measured background clutter level of 10^{+} dBsm for the terrain at the test site. Hence the target probably would be undetectabie by many airborne radars with the same antenna aperture at this elevation angle unless the broadside and front/rear flashes were observed. Naturally, this conclusion does not apply to modern radar systems such as those employing large synthetic apertures or moving-target indicator (MTI) beam shaping techniques in their normal modes of operation.

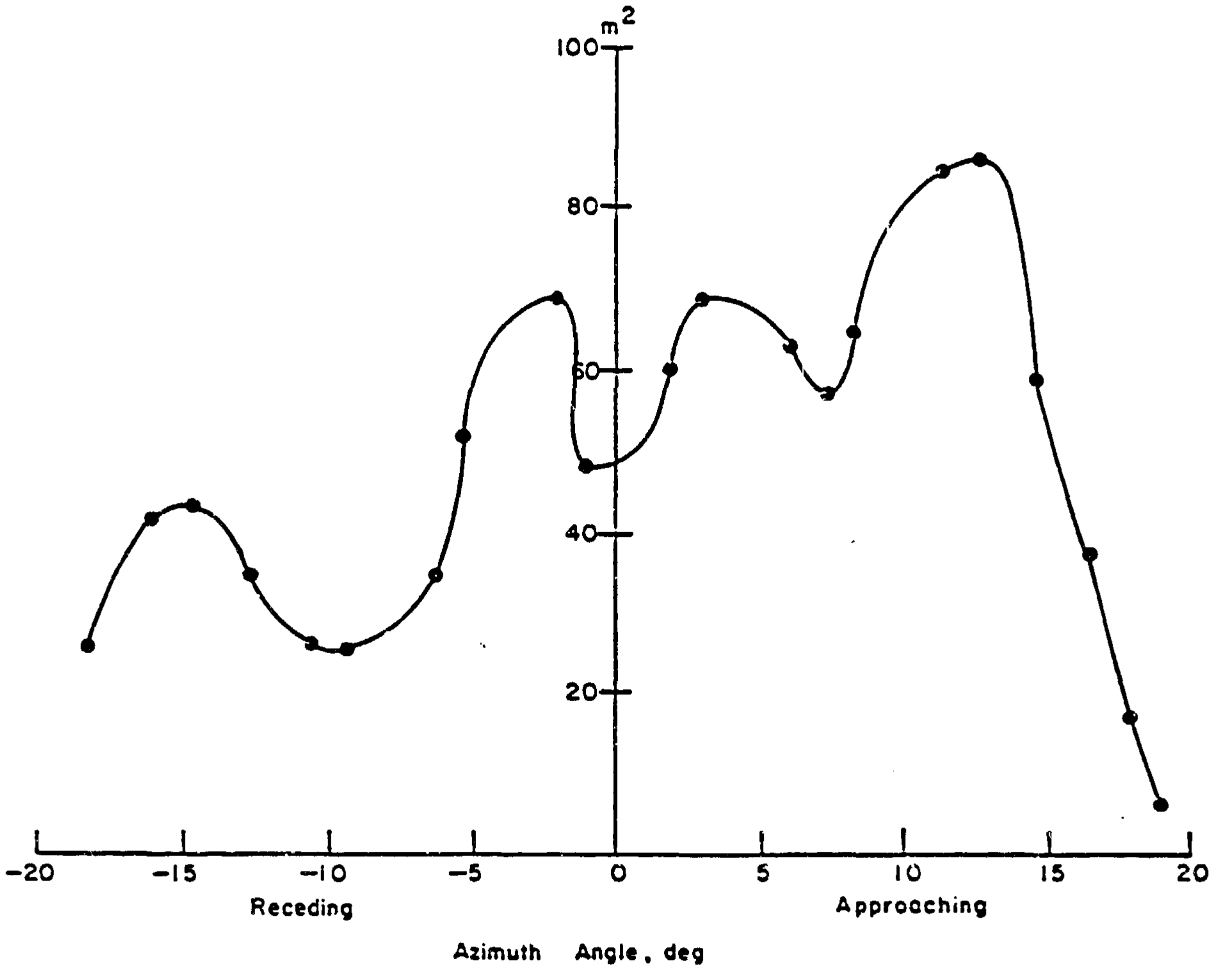

Figure D-8. Cross-Section of a Tank at 140 MHz

Table D-3. Range of Cross-Sections of Grazing Aspects.

Vehicle	Frequency, MHz	Polarization	Cross-Section, m^2	
			Near Head-on	Near Broadside
Jeep	1180	H	58.2 - 92.2	59.3 - 186.7
		V	-	59.3 - 186.7
	9375	H	250 - 1120	470 - 1480
		V	90 - 219	240 - 589
2 1/2-ton truck	1180	H	35.7 - 219.7	612 - 2712
		V	36.6 - 211.8	612 - 2712
	9375	H	330 - 1590	407 - 725
		V	324 - 603	190 - 890

Ref: Comprehensive Target Signature Measurement Program, 3rd Interim Technical Report, Univ. of Michigan, Feb. 1966.

Table D-4. Median X Band RCS of Military Vehicles.
(Low grazing angle, horizontal polarization)

Vehicle	Median RCS, M^2
Tank (M4A2-Sherman)[a]	20 (med) 200 (max)
Sedan (1955 Ford)[b]	72
Tank (M-48)[c]	185 (avg)
3/4-ton truck (M-37)[b]	480
Shop van (M-109)[b]	780
Jeep (M-38A1)[b]	790
Tank (M-47)[b]	1250
2-1/2-ton truck (M-35)[b]	2560
5-ton truck (M-54)[b]	3230

(a) Canadian Armament Research Establishment; measured at 3.5° and 5.4° depression angles.
(b) Willow Run Laboratories.
(c) Georgia Institute of Technology.

Ref: Comprehensive Target Signature Measurement Program, 2nd Interim Technical Report, Univ. of Michigan, June 1966.

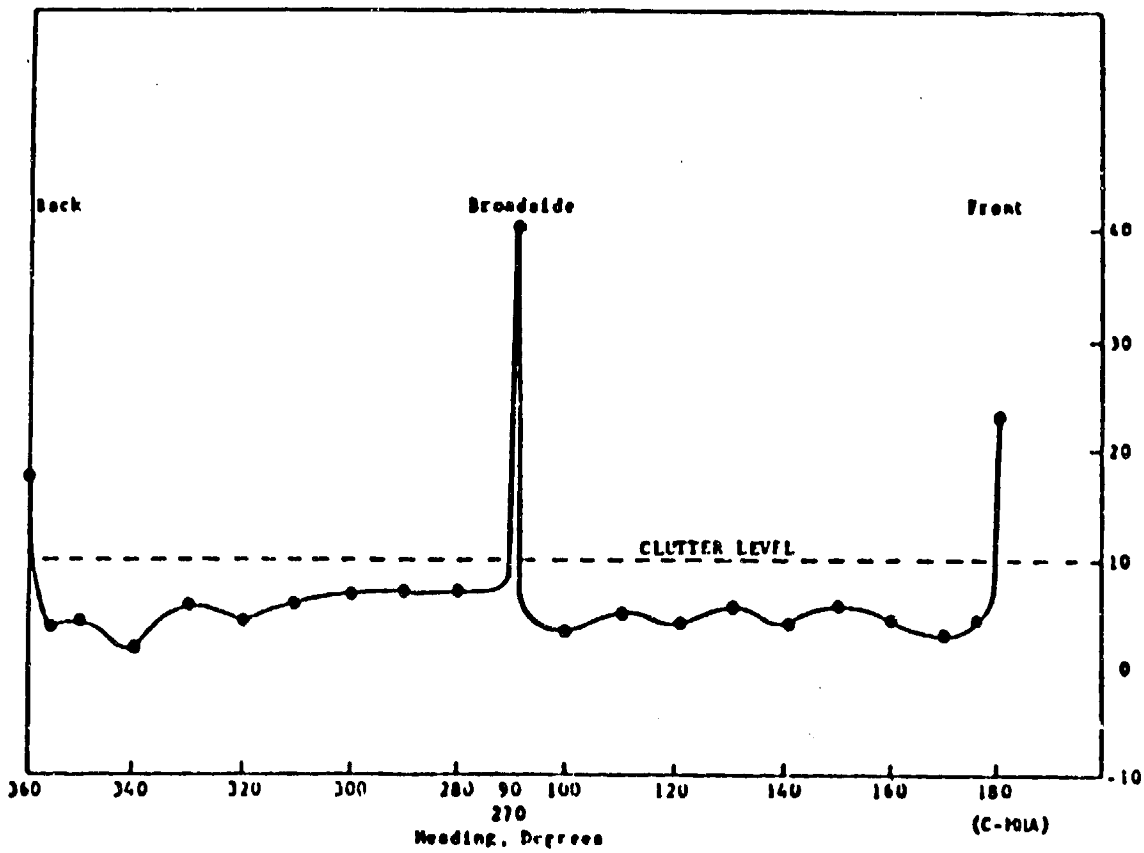

Figure D-4. Cross-Section of M-113 Armored Personal Carrier VS Azimuth

Although no details are presented here, the application of dual polarization techniques and frequency agility over wide bandwidths with advanced digital signal processing, phase comparison and high resolution imaging radar methods are significant for future camouflage technology development. Where 5-10 target features are usually more than enough for discrimination and recognition of most tactical targets, the prospects for fine signature analysis and multidimensional discriminant algorithms are likely to give RSTA systems on the order of 100 target features. The challenge to camouflage in the future is quite evident.

D-6 MILLIMETER WAVE SYSTEMS

Advantages of the millimeter-wavelength spectrum for military use are the wide bandwidths, larger gain and narrow beams from small-aperture antennas that permit penetration of fog and clouds and the detection, covertly if necessary, of military targets whose surface properties differ greatly from the natural backgrounds. The limitations are in the power required to achieve even moderately short ranges and the sensitivity to atmospheric absorption except in the atmospheric "windows" that are centered at 35, 94 and 140 GHz. A plot of the one-way attenuation per kilometer for horizontal MMW radar propagation in clear air is shown in Figure D-5. Increased immunity to detection by opponents and to friendly interference as well as enemy ECM are favorable consequences of small beamwidth and lower side lobes.

In comparison with optical and infrared sensors, the radiometric qualities of the sensors in the millimeter waveband give them greater sensitivity to target temperature but with lower resolution. Increased resolution can be obtained at the shorter millimeter wavelengths, e.g., 140 GHz and above. Higher frequencies permit lower power, compact solid state systems that achieve greater detection and recognition probabilities of tactical targets against terrain clutter at reasonable ranges (e.g., up to 5 km) but at some sacrifice of greater attenuation loss under adverse weather conditions. For "smart" weapon the important features of MMW are small angular beamwidth, high sensitivity to doppler MTI and small package size. In any case, target recognition is important but sensitive to background clutter in the immediate vicinity of the target and observer skill becomes an important recognition parameter.

The narrow beamwidth of MMW systems discriminates against multi-path and clutter signals. In addition, discrimination of smooth man-made target surfaces is possible because of the contrast between these surfaces and the rough surfaces of natural objects at these short wavelengths. In the passive mode, this contrast appears as emissivity differences between the high emissivity of natural backgrounds and the low emissivity of smooth man-made objects. For camouflage purposes, a target is considered detected if it is represented on a display as a "spot" discernable against background noise and hence a candidate target. Recognition by shape implies that the observer concludes on the basis shape that the "spot" is probably a target. MMW sensor systems now beginning to appear provide performance that is far greater than these simple requirements.

Availability of high-power MMW energy through the development of high-power oscillators/amplifiers such as the gyrotron has advanced military applications in airborne radar as well as communications. The MMW radar applications permit very high data rates due to the high frequencies (e.g., 10-300+ GHz) involved. Within the low-loss "windows" of the atmosphere, the very narrow beam, high resolution antennas being developed make possible the focussing of the energy into very small, high-

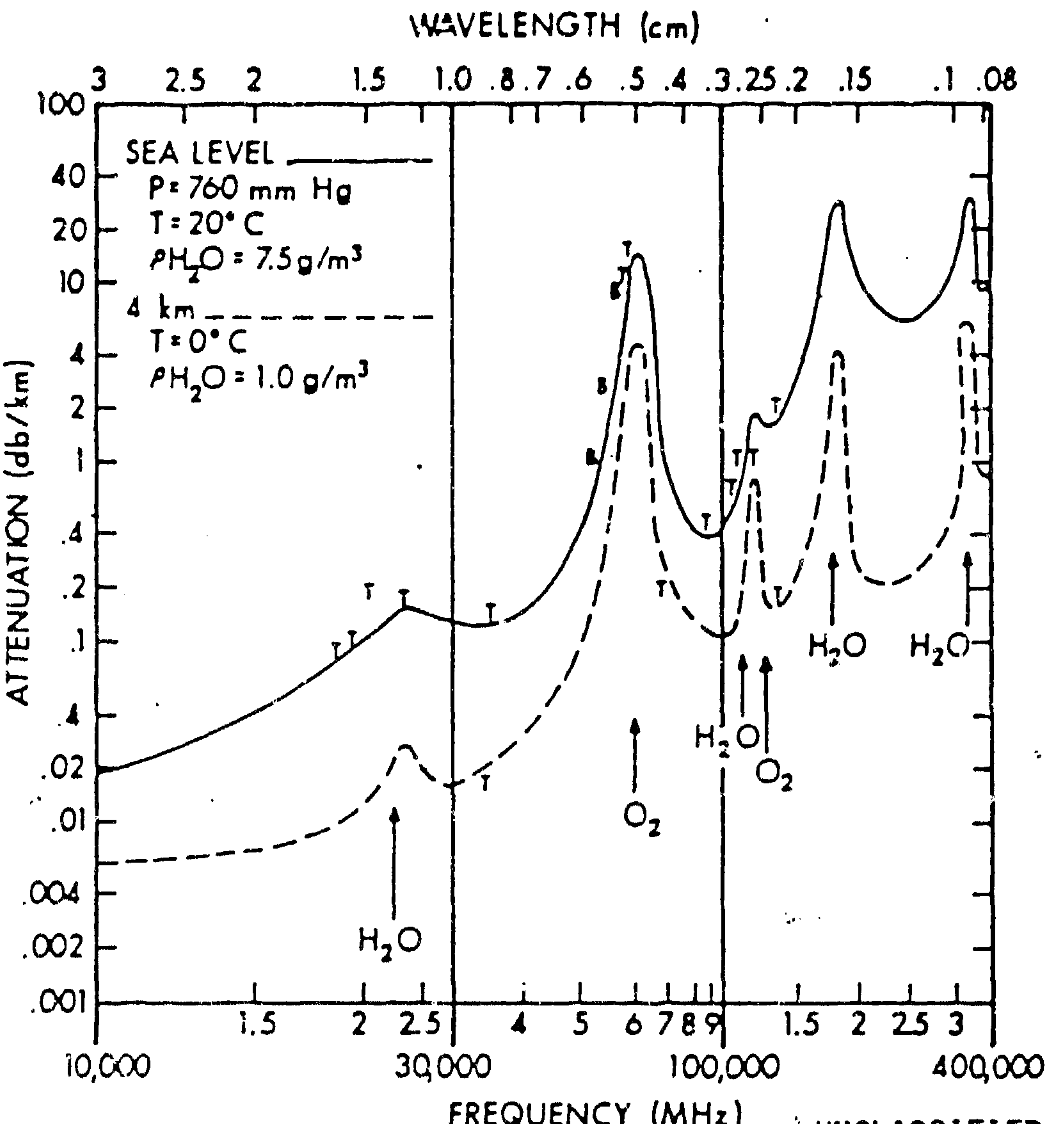

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Figure D-5. One-Way Atenuation per Kilometer for Horizonal MMW Radar Propagation in Clear Air

resolution volumes on the targets. However, MMW radar capabilities and design requirements are known and understood by many different groups around the world and, in the future, may be expected to oppose U.S. targets with or without camouflage at various threat levels.

A typical MMW radar for airborne use would be likely to provide multiple functions; for example, object detection, target acquisition, ground mapping, MTI against tactical targets and fixed target enhancement using polarization to detect targets in clutter. Applications of MMW in terrain avoidance/terrain following, multimode target attack by smart munitions and pairing with IR or laser for RSTA and weapon guidance/navigation are already appearing in advanced weapons systems development. Combinations of high-power, mixed and multimode sensors in integrated RSTA systems packaged with powerful microprocessors suggests certain camouflage technology needs to meet such developing threats. Target discrimination algorithms that are very selective and target specific have now become possible and target signature modification has become necessary for survival.

Sensor-target interactions in the passive radiometer mode depend on the sky brightness temperature illuminating the targets-backgrounds and their irradiance (m/cm^2/ster), radiometric temperatures and signature polarization. The target-background reflectances, emissivities and emissivity/radiance contrasts reveal target "cold spots" and target "glint." Camouflage can modify these responses and alter detection/recognition/location of the targets.

Active MMW interacts with targets/backgrounds through high angular resolution of scatterers, spatial and spectral signatures, polarization response and comparisons of energy returns from periodic scans of the target/background scenes. Camouflage can interfere with the discrimination of natural and man-made objects, especially metallic targets.

The problem of contrast reversal due to sley brightness temperature variations with moisture, local thermal conditions and materials with low microwave reflectances (i.e., metal and water) in certain temperature ranges causes difficulties for MMW shich camouflage may exploit. However, since most materials exhibit high microwave emittances in MMW wavebands and many common materials (e.g., vegetation, soil, concrete and rock) also exhibit microwave emittance, the thermal conditions tend to determine the contrast reversal and predictability here is poor. For active imagery radars, the governing electrical property of the targets/backgrounds is reflectance and hence they are relatively insensitive to the complex time-varying atmospheric and meteorological effects. They are, however, very sensitive to background clutter and target signal-to-noise ratios and camouflage has obvious opportunities to influence RSTA interactions in appropriate ways.

D-7 TARGET SIGNATURE MODULATION AND SYNTHESIS

Controlling target signatures to reduce the probabilities of detection, identification and target acquisition by threat RSTA systems takes on increasing importance as RSTA capabilities increase. The prospect of smart, multisensor, aggressive RSTA's employed as ground and air surveillance and target acquisition systems threatens the mobility, survivability and combined arms effectiveness of the maneuver forces.

Suppression of target emissions and responses to sensor interrogation can reduce signal amplitudes and characteristics available for coordinated sensor operation. Technology base efforts should address visual, IR, RF, microwave, milimeter wave, magnetic and acoustic signatures and the temporal surrounding of the natural environment to find the most effective means of reducing signatures. Technical means should be sought to suppress, filter, confuse, modulate or clutter these signals individually and in combination to defeat multisensor RSTA systems. Shape, color, texture and shadow may be modified for visual sensing. Thermal contrasts and amplitude/spatial profiles may be controlled. In the microwave regions, the radar cross sections, reflectances, polarizations and emissivities are candidates for detection/ discrimination avoidance. For magnetic or acoustic phenomena, control of characteristic amplitudes, frequencies and orientation of the signatures is possible.

Attributes of target signatures can vary widely with the type of target, encounter conditions, scene content and sensor/processor responses to signature modulation. The requirements for adequate measured and reliable data can be met only with comprehensive measurements data base development.

Advancing technology has introduced effective means for modulating and synthesizing tactical target signatures as observed by reconnaissance, surveillance and target acquisition sensors. Camouflage systems can attempt to deny effective functioning of threat RSTA system sensors by using electronic, electrical, mechanical, magnetic, acoustic, optical or other means to actively or passively deny/subvert those sensors and their data processors. Deliberate introduction of physical phenomena affecting target emissivity, spectral response, cross section, polarization, surface texture or multispectral "color" for example, can cause decision errors and failures of the RSTA systems and thus enhance survivability, mobility, and surprise favoring friendly forces.

Signature synthesis (e.g., "make a tank look like a truck") can have immediate tactical goals. It can be designed to draw fire away from real targets by creating false targets or decoys. It can decrease the threat sensor systems utility by causing false alarms or critical malfunction of the sensors. The overall result is to compromise the RSTA operation through signature synthesis of tactical targets, simple as well as complex.

Technology base developments include advanced versions of strong electromagnetic field generators, moving charged wires/bodies, superconductor devices, or electric discharge phenomena to trigger inappropriate or erroneous sensor responses. Acoustic or ultrasonic techniques for masking unique tactical signatures or imitating high-value target emissions can make use of new transducer applications technology to raise false alarm rates and induce sensor system overloads. Active/passive IR generators, reflectors, "hot spot" simulators, high-intensity flash devices, hot chaff-smoke and thermal profile simulators are among many other candidates for counter-RSTA applications. More sophisticated signal generators/repeaters in microwave and millimeter wave spectral regions must also be considered in simulative/imitative/ manipulative modes for counter-RSTA use against future aggressive RSTA systems. Signature projection by using camouflage devices such as the holographic response devices, mirrors and active EM transponders may provide camouflage action against a variety of intrusive sensor interrogations.

D-8 INTELLIGENT SENSORS AND MULTISENSORS (MIXED, MULTIMODE)

D-8.1 Introduction.

Technology advances in individual sensors generally strive for increased sensitivity and bandwidth, lower noise, reduced size/weight/power, all-weather operations, environmental hardness, EW compatibility, and lower cost. Advanced sensor technology provides an "edge" -- a critical performance advantage in many weapon systems -- over C3D capabilities. Advanced technology for RSTA sensors can enhance detection, discrimination, fusion, pattern recognition, real-time classification, location, threat assessment, and overcome neutralization actions.

In general terms, a sensor is any information gathering component that detects signals or emissions including reflected signals from target objects, the surrounding media, or other temporal phenomena. It provides input for processors and readouts of various kinds. Sensors depend on a variety of physical phenomena such as visible light scattering, infrared scattering, multispectral radiation emissions or scattering, radio frequency emissions, magnetic anomaly, or acoustic vibration. In one form or another most sensors find application in anti-camouflage warfare with varying degrees of efficiency and effectiveness.

Table D-5 summarizes some generic sensor candidates for RSTA applications along with certain characteristics and limitations. A preference for certain combinations of these sensors in RSTA warfare systems would depend on operational requirements and tradeoffs. Camouflage development efforts should examine these technology applications to select most likely alternative multisensors that may emerge. High resolution video sensors may reveal distinct patterns of target emplacement. Acoustic sensors may detect and locate camouflage support operations. Chemical sensors may isolate and identify unique effluents or emanations near certain types of targets. Active IR and MMW may observe unique target signatures and fine structure responses that discriminate target objects in cluttered environments on the battlefield.

Combinations of mixed/multimode sensors in projected integrated RSTA systems packaged with powerful, coherent processors suggests technology base needs to anticipate and surmount expected camouflage difficulties with mixed/multimode phenomena and to avoid or reduce target signature exposures. This implies developing camouflage capabilities to match/overlay diverse sensor data in real-time and to anticipate C^3 digital/analog/logic constructs from RSTA/intelligence sources. Examples of mixed/multimode sensor combinations that may be encountered include the following:

D-8.2 Millimeter Wave/Microwave.

Combining passive and active MMW/MW sensor/communications systems with multi-dimensional algorithms using techniques such as spatial phase resonance, fine structure analysis, scan demodulation, doppler/beam shaping, MTI, modulated polarization, and frequency agility can permit full utilization of advanced microprocessor capabilities and integration of at least 10-100 or more target features/discriminants including surface textures and vibrations. Conformal antennas, efficient/phase coherent/wide bandwidth transmitters, relativistic devices, and extremely-low-noise broadband receivers/signal processors designed in the form of monolithic microwave integrated circuits (e.g. gallium arsenide, et al.) may allow RSTA applications to exploit the microprocessor signal processing capabilities now becoming available.

Table D-5. Generic Sensor Candidates for RSTA Applications.

SENSORS	TARGET DETECTION PROBABILITY	FALSE ALARM RATE	PHYSICAL AND ENVIRONMENTAL LIMITATIONS	VULNERABILITY TO COUNTERMEASURES
IR PASSIVE	TARGET/BACKGROUND T AMPLITUDES GIVE HIGH DETECTION PROBABILITY WITHIN LOS.	SPATIAL DISCRIMINATION AND/OR TIME INTERVAL OF T (LOGIC) SERVE AS DISCRIMINANTS AGAINST FALSE ALARMS	FIELD OF VIEW AND LOS CAN BE DISRUPTED; RAIN, SNOW, SMOKE, FOG, FROST, VEGETATION, DUST, AND DEBRIS ATTENUATE SIGNALS.	IR FLARES/SPATIAL OR TIME PULSED; HOT CHAFF - SMOKE; LOS SCREENING (ANY MATERIAL).
IR ACTIVE	REFLECTANCE AND EMISSIVITY CORRELATION GIVE HIGH DETECTION PROBABILITIES.	PULSE CODE AVOIDS MOST FALSE ALARMS/SPOOFING.	FIELD OF VIEW AND LOS CAN BE DISRUPTED; RAIN, SNOW, SMOKE, FOG, FROST, VEGETATION, DUST, AND DEBRIS ATTENUATE SIGNALS.	IR BEAM INTERDICTION; REFLECTORS OR MIRRORS; HIGH-INTENSITY FLASH.
MICROWAVE	DOPPLER AT X-BAND (10 GHz) GIVES HIGH DETECTION PROBABILITY FOR TARGETS IN MOTION.	LARGE TARGETS BEYOND AREA OF INTEREST MAY CAUSE ALARMS, TRADEOFF; NUISANCE ALARMS VS. SENSITIVITY.	LIMITED FREQUENCY RESPONSE OF DOPPLER FILTERS LIMITS SIGNAL PROCESSING; SNOW AND ICE, RAIN AND VEGETATION DEGRADE SIGNALS.	REFLECTORS, JAMMERS, RESPONDERS; REQUIRES SIGNAL PROCESSING CCM.
MMW (RADIOMETRIC)	LARGE COLD TARGETS (ARMOR) HAVE HIGH CONTRAST WITH MOST BACKGROUNDS AND HIGH PROBABILITIES OF DETECTION.	REFLECTIONS (OFF-TARGET) AND CLUTTER CAUSE HIGH FALSE ALARM RATES UNLESS MULTI-FREQUENCY OPERATIONS IS POSSIBLE.	NATURAL ENVIRONMENT (E.G., WATER, SNOW, FOLIAGE, ROADS) CAN LIMIT EFFECTIVENESS; SNOW AND ICE, RAIN AND VEGETATION DEGRADE SIGNALS.	FALSE TARGETS REQUIRE SIGNAL PROCESSING CCM.
MMW (ACTIVE)	HIGH RESOLUTION PULSE-CODED RADARS GIVE HIGH PROBABILITY OF DETECTION AGAINST ARMOR.	REFLECTORS/REPEATERS (ON TARGET) AND CLUTTER CAUSE HIGH FALSE ALARM RATES UNLESS MULTI-FREQUENCY OPERATION IS POSSIBLE.	NATURAL ENVIRONMENT (E.G., FOLIAGE, SNOW, BUILDINGS) CAN LIMIT EFFECTIVENESS; SNOW AND ICE, RAIN AND VEGETATION DEGRADE SIGNALS.	FALSE TARGETS REQUIRE SIGNAL PROCESSING CCM.
MAGNETIC	HIGH PROBABILITY OF DETECTION OF FERROUS METAL OBJECTS IN MOTION; TANKS, BOGEYS, TRACKS, ENGINE COMPONENTS.	LOW IF DIPOLE THRESHOLD IS SET HIGH FOR LARGE ARMORED VEHICLES, SEISMIC VIBRATIONS CAN CAUSE NUISANCE ALARMS AT A FEW METERS RANGE.	SINGLE PT. MAGNETOMETERS HAVE A CONFINED SENSITIVITY RANGE, 30-50 METERS. FREEZING TEMPERATURES, GROUND WATER, NEARBY ELECTRIC POWER DISTRIBUTION, AND LIGHTNING CAN ADVERSELY EFFECT THE SENSORS.	FALSE ALARMS BY VIBRATING METAL OBJECTS (E.G., CHAIN LINK FENCES, METAL BLDGS., SWAYING WIRES, NEARBY TRAFFIC).
SEISMIC	SENSITIVE ELECTROMAGNETIC "GEOPHONES" HAVE HIGH PROBABILITY OF DETECTION OF STRONG VIBRATIONS FROM HEAVY VEHICLES.	FILTERS DISCRIMINATE NATURAL SEISMIC DISTURBANCES BUT SENSITIVITY TO LOUD, MAN-MADE NOISES (EXPLOSIONS) AND VIBRATIONS (POWER SOURCES) IS A PROBLEM.	HEAVY VEHICLES MASK LIGHTER ONES; ENVIRONMENTAL FACTORS: LIGHTNING, THUNDER, RAIN, HAIL, GROUNDWATER, FREEZING TEMP., WIND INTERFACES WITH TREES/VEGETATION AND WATER WAVE ACTIONS IN RIVERS/CREEKS; SIGNAL ATTENUATION VARIES WITH EARTH MEDIUM.	ARTILLERY, LOW-FLYING AIRCRAFT MIMIC SIGNALS, INDUCED VIBRATIONS FROM ENGINES, TURBINES, PUMPS, BLOWERS, GENERATORS, EARTH-DIGGERS CAN CAUSE FALSE ALARMS.
ACOUSTIC	MICROPHONE TRANSDUCERS SORT OUT RICH ACOUSTIC SIGNALS BY FREQUENCY/AMPLITUDE/DURATION (100-8000 HZ) FOR HIGH PROBABILITY DETECTION/ CLASSIFICATION OF TARGET.	LOW THRESHOLDS INVITE HIGH NUISANCE/FALSE ALARM RATES AND RANGE VS. THRESHOLD TRADEOFFS.	AMBIENT NOISE BACKGROUND INCLUDES BATTLEFIELD NOISE; MAY MASK/ FILTER ARMOR SIGNALS; SENSORS VULNERABLE TO RAIN, SNOW, GROUND WATER, FREEZING, WIND, LIGHTNING, AND THUNDER.	ARTILLERY, LOW-FLYING AIRCRAFT MIMIC SIGNALS; NOISE GENERATORS CAN MASK TARGET SIGNALS.

Sensor technologies mentioned above, and others, should be explored exhaustively in the camouflage technology base design efforts in order to pursue major goals in camouflage efficiency and overcome C^3I, integration, and realization of the ultimate tactical advantages of using remote RSTA systems.

In the optical multisensor area, multispectral imaging, opto-electronic devices, clutter control, and discriminant synthesis developments may lead to integrated IR scene analysis and new threat RSTA system detection/discrimination capabilities.

D-8.3 Infrared/Optical/UV.

Combined imaging and non-imaging electro-optical RSTA sensors will involve advanced digital electronic and photo-amplifier technologies across a broad frequency spectrum (UV to 30+ microns) and the technologies of focal plane arrays, programmable spectral filters, advanced cryogenics, and advanced signal processing. The search, track, discrimination, and countermeasure algorithms of these combined electro-optic sensors challenges camouflage and emission suppression to stay ahead. Camouflage developments ust anticipate significant applications here, especially in CCD (Charge Coupled Device) fiber optic designs, and microchip monolithic integrated circuitry and opto-electronic techniques. These design approaches may permit surface mounting of RSTA sensors on the composite substrate exteriors of the tactical maneuver vehicles, robots, or RPV's in the most appropriate deployment modes.

Recognition of the potential multisensor capabilities of bi-modal (binary) or multi-modal sensors in RSTA roles has stimulated new interest in acoustic/ magnetic technologies. In addition, the recent advances in new superconductor materials (e.g., CMOS combinations like Lanthanium/Barium/Copper oxides with transition temperatures above 40°K or even 70°K that can be cooled with liquid nitrogen) superconducters vastly increase the potential sensing capabilities of magnetic and acoustic detectors such as SQUIDS and other devices that may be used in conjunction with RSTA sensors to spy on tactical targets.

D-8.4 Acoustic/Magnetic.

Magnetometers, for example, using NMR (Nuclear Magnetic Resonance) sensing or fiber optic techniques or SQUID/JJ technology to obtain gradiometric measurements and field dipole amplitudes/movements offer exceptionally reliable, sensitive, and versatile target signature detection. Appropriate systems designs may become extraordinarily effective with applications of new superconductive elements. Microphones consisting of new materials (e.g., thin films of zinc oxide on silicon substrates) can provide small, light, reliable, high S/N low power (40 mw) IC devices to detect any acoustic signatures and resonant vibrations in multi-modal systems. Combined multisensors promise very high quality, correlated target detection and discrimination capabilities which camouflage may be called upon to neutralize.

D-8.5 Artificial Intelligence (AI) Algorithms.

Basically, artificial intelligence (AI) refers to the technology enabling machines, including sensor systems, to choose and implement particular functions when faced with several alternative possibilities. AI draws upon technology advances in microcircuits, robotics, and the heuristic/symbolic power of advanced computer developments. In contrast with conventional algorithmic approaches, AI systems are intended to be more

robust and to deal with problems exhibiting uncertainty and ambiguity. AI algorithms would have the ability to first determine the critical aspects of sensing problems, for example, and then assign sensor and computational resources to solve these problems. Camouflage may be required to utilize similar technologies to adaptively respond to RSTA probes.

AI multisensor approaches not only integrate diverse multisensor information but diagnose/correct sensor functions, autonomously redirect surveillance/detection/processing routines and choose alternative operating modes to obtain acceptable results. These actions might involve, for example, reprogramming autonomous on-board robots to improve task performance or correct sensor assignments/attitudes when scene conditions shift or deciding which physical movements of a robot sensor platform are needed to better observe some countermine target. The camouflage detection and discrimination concepts for the future require capable, autonomous countermine intelligence-gathering systems organic to the maneuver elements. Working against camouflaged targets, these AI multisensor systems could include remote sensors, microprocessor computers at sensor and command levels, secure information flow channels, and real-time display devices. Camouflage designs would use similar technologies to react and neutralize the RSTA.

Technology base efforts toward the use of AI for camouflage operations might take the form of system development as shown in Figure D-6. An RSTA detection/discrimination system incorporating AI might envisage an expert hypothesis formation system containing input data from multisensors (visual, IR, radar, MMW, etc.), a reasoning process, a knowledge base, and a hypothesis (existence or non-existence of sensors) as output to the user. The knowledge base would consist of both feature extraction algorithms and heuristic rules for interpreting those features. The reasoning process selects the next appropriate heuristic or algorithm for refining the current set of hypotheses concerning the optimal camouflage reaction/response.

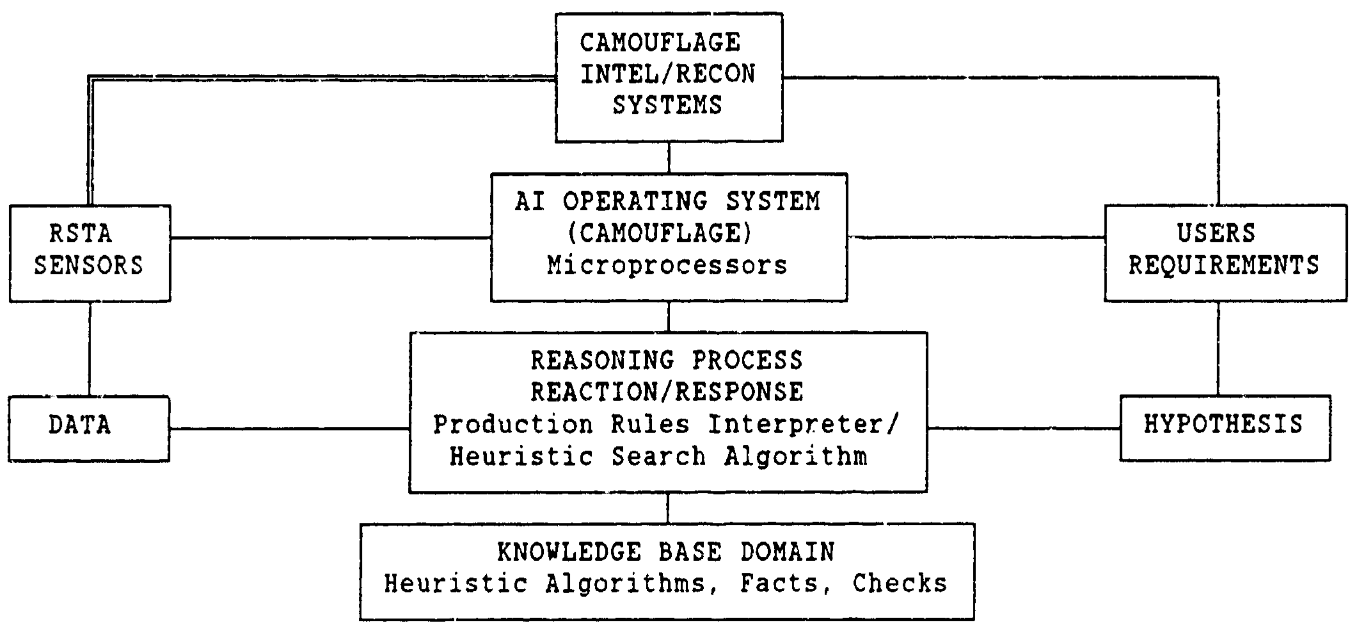

Figure D-6. Simplified Structure of Knowledge-Based Hypothesis Formation System.

A technical approach to realization of such an AI system might take the following form:

- Formulate characteristics of the camouflage detection/discrimination system for RSTA and components in accordance with the concepts of operation.
- Determine camouflage system specifications including consideration of likely threat platforms and which microprocessors and AI algorithms are available.
- Synthesize the detection/discrimination system from the various candidates based upon optional interfaces available for knowledge base design.
- Evaluate system operational features and performance to identify information flows/needs and to refine the procedures necessary for system integration.
- Develop prototype system identifying the specific constraints, demands, performance objectives, and schedules necessary to ensure successful system integration.

D-9 SENSOR FUSION CAPABILITIES

Integration of counter-RSTA information from diverse tactical, instrumental, and human sources in near-real-time is a fundamental goal in fusion technology for development and system design. Data acquired from various instruments, air/ground sensors, and situation/simulation mosaics must be processed and correlated to produce a single coherent output (or pattern) useful for RSTA threat validation, neutralization decisions, and tactical maneuver C^3. Digital signal processing techniques make possible very high speed integration of acoustic, IR, radar, optical, biomedical, and communications signals.

Fusion processes in general contemplate extensive use of situational input data, knowledge bases, CCM techniques, SIGINT, imagery, and correlated sensor information to provide timely unambiguous target detection and classification. Camouflage must do the same against RSTA. The simplest examples of fusion are those that process, correlate, and communicate data and corollary information for co-located multisensor equipment (e.g., on-vehicle systems) where the coordinate systems, viewing angles and geometry aspects are established *a priori*. More complex processes are designed to deal with ground/air/space data integration, tactical intelligence correlations, selective digital filtering, and pattern recognition algorithms. With RSTA advancing so quickly, camouflage msut absorb these more complex processes as well.

Fusion for system applications involves hardware and software structures for acquiring and processing information in a collaborative system that can:

- Interpret/correlate potential acoustic, magnetic, radar IR, and optical intelligence,
- Conduct the necessary communications filtering, multiplexing, switching, and interface translation, and

- Conduct spread-spectrum, CCM, and packet switching that may be necessary to counter offense-integrated RSTA systems.

At the module level, these functions may incorporate intelligence input data processing, work station operation, integration with forward sensors, and many C^3I communications just as they do with advanced RSTA operations.

System requirements for fusion must be developed in the camouflage technology base to guide the design applications of these complex processes and their modular realizations for counter-RSTA systems.

D-10 DISTRIBUTED INTELLIGENCE CAPABILITIES

It is widely recognized that abundant tactical information valuable for RSTA purposes may be available on the battlefield but not accessible to the sensor systems. Continuing developments in the technology base would make maximum use of telecommunications technology, advanced all-source analysis, and automated tactical fusion capabilities to provide unprecedented access to useful target information and intelligence through these sources. Camouflage advances can make use of the same technologies to actively enhance performance against the improved RSTA systems.

For RSTA, distributed intelligence concepts are concerned with utilizing tactical data elements separate from the sensor systems to perform or support detection/discrimination, data processing, destruction/neutralization, and damage assessment functions that contribute to performance. For camouflage, effective use of scan warning, EW signal analysis, feature simulation, and new transducer materials to adapt camouflage actively under attack can keep camouflage capabilities abreast with the RSTA advances. The technology base should concern itself with moving and manipulating information gathered for/by RSTA sensors/systems. This information is for use by tactical commanders and intelligence evaluators and by machines in the CM system. Tech base CM work should pursue work in at least three main development areas.

- Camouflage responses to RSTA signal processing dealing with advanced architectures and techniques, adaptive antennas, ECCM, anti-jam, and injection of VHSIC/MMIC circuitry should use these technologies to develop new concepts.

- Camouflage should exploit communications links and link mechanisms including satellite relays, optical links, LOS/tropo links for survivable communications on the intense, fluid battlefield.

- Total systems control designs/analyses to enable development of camouflage with effective/efficient switching/routing of information and data for distributed intelligence gathering and for camouflage responses in the spectral, spatial and time domains.

Systematic use of distributed intelligence capabilities implies corroborative, correlated near-real-time sensor/communication links (fusion) with integral computer processing support. RSTA is already hard at work on these advanced techniques. Anticipated camouflage system performance levels will incorporate fusion capabilities as well as spread-spectrum and very high data rate systems (now under development).

Additional features may include high-speed circuit switching, teleconferencing, encryption, commlink filtering/processing, and matrix switching in network operations, the same techniques being developed for advanced RSTA systems.

D-11 ADVANCED SIGNAL PROCESSING

Signal processing includes all techniques and procedures for extracting information from a signal. Modern methods employ digital processing to perform real-time analysis to estimate signal parameters or to transform a signal into more suitable forms for further processing.

Older RSTA threat sensors have made use of simple amplitude thresholds or time domain algorithms. Advanced RSTA increasingly depends on complex signal processing algorithms for effective utilization of more extensive and complex sensor data now available. The advanced RSTA signal processing will similarly involve some or all of the following:

- High resolution A-D conversion,
- Clutter reduction,
- Image sharpening,
- Improved target discrimination,
- Pulse compression using low peak power but high average power,
- Instantaneous bandwidth spread spectrum techniques, and
- High speed digital storage and retrieval.

Recently, integrated solid-state designs have demonstrated effective computation with Fast Fourier Transforms (FFT), coherent phase processing, and sensor array processing (e.g., CCD/fiber optic designs). Camouflage can expect to endure close, highly intrusive interrogation when facing the newer RSTA threats.

To eliminate deleterious effects, adaptive processing and signal processing in complex high density EM environments may be needed to counter frequency agility, low probability of interrupt (LPI) phased array controls, and acoustic/optic spectral analysis. All of these techniques for RSTA applications will depend upon high speed microprocessors, complex signal processing algorithms, and recent advances in VHSIC/VLSIC/MMIC to achieve their tactical goals.

The camouflage interaction technology base should be concerned with advanced signal processing software development, including concept formulation, definition of requirements specifications, software design/production and test, as well as operation and maintenance of applications software for future camouflage systems. Although design/production/testing may be done by software specialists, it is essential that the technology base provide on-going design integration efforts to develop requirements and specifications for new interaction concepts and their ultimate use. These design/concept system integration efforts would allow maximum advantage to be taken of the current surge in signal processing technology capabilities.

Effective management of the technology base software development processes is critical for achieving practical results in future camouflage applications. A broad based effort is essential to absorb and utilize emerging capabilities in sensor fusion, distributed intelligence, adaptive fuzing, artificial intelligence, IFF, and secure C³I networks. Reactive camouflage applications software can now take advantage of

VLSIC/VHSIC/MMIC and new advances in integrated optics with thin film/fiber optics components for generating, detecting, modulating, switching, and directionally coupling signals at optical wavelengths in rugged, secure processor designs. The technology base should exploit the exceptional capacity, security, flexibility, and adaptability now available in advanced digital signal processing to design and implement counter-RSTA systems that will be highly target selective, CCM resistant, controllable, and secure on future deception-integrated battlefields.

D-12 MULTIMODE LOGIC

Development of intelligent processing should be a prime activity in the camouflage system technology base. Utilization of multimode sensing and the search for improved countermeasure resistance are generating increasingly complex processing/decision algorithms. Sensor algorithms are expected to make best use of burgeoning microprocessor capabilities to detect and classify target signatures in real-time with a high degree of reliability and flexibility. At the same time, sensor system constraints must be met such as low cost, small size and very low power dissipation, at least for those RSTA modules that are with the maneuver forces.

Camouflage advances should consider similar microprocessor based multimode logic. Multichannel inputs consisting of transducer signals that respond to magnetic, seismic, acoustic, infrared, microwave, millimeter wave optical/electro-optical interrogation can be used singly or in combination. Realistic response to the monitoring, feature extraction, spectral analysis and classification logic in real-time processing has only became possible recently with microprocessor technology advances, VHSIC/VLSI and monolithic integrated circuits (MMIC) and parallel processing.

The camouflage technology base should investigate available monolithic hardware for system applications. The MMIC's can use sophisticated pattern recognition functions and time series wave form analysis for combined sensor analysis that is appropriate for response decision functions. Camouflage system design efforts must take advantage of compatible hardware and software developments, signal processing requirements, Fast Fourier Transforms (FFT), linear/nonlinear discriminants, pattern recognition functions, and decision trees unique to the camouflage/RSTA competition.

Algorithm approaches to the multimode action logic perform all the processing on signals received by the sensor transducers to extract necessary intelligence on what the representative signatures are. Based on preprogrammed combinations of spatial and statistical processes, specific algorithms for the data base of representative threat RSTA system signatures will lead to decision making on valid target camouflage action decisions.

The camouflage technology base analysis work can determine which are the preferred response to target classification technique using mixed sensors (e.g., acoustic/magnetic, thermal/MMW) as well as mulitimode sensors (e.g., IR imaging/IR non-imaging, MMW passive/MMW active). Severe problems exist in sensor data cross correlation and pair-wise fusion for analysis and decision making in most current applications. Technology base efforts aimed at understanding effective logic processes must support design and development of the sensor/algorithm tasks. Although it may sometimes be preferable to have sensor and algorithm development done at other laboratories and technical skill centers in order to gain expertise, the integration into effective image/correlation processors, target recognition and identification algorithms

for camouflage systems must take place in the RSTA/camouflage technology base. This will assure balanced and effective concept development for advanced camouflage that can intelligently respond to emerging sensors, target signature, attributes, signal processors and analysis/simulation structures being used in intelligent processing for advanced RSTA system applications.

D-13 DISCRIMINANT LOGIC (ADAPTIVE ALGORITHMS)

Potentially autonomous future RSTA systems may use adaptive algorithms to adjust discriminant weighting, sensor updates, or decision paths during engagements. RSTA actions could be made more vulnerable to camouflage techniques.

Adaptive algorithms are likely to expand the techniques of pattern recognition and scene analysis already employed in some sensor signal processing for surveillance and target acquisition. Availability and use of corroborative and correlative discriminant processes are important areas for camouflage technology base investigation.

Concepts of adaptive control and fuzing are already appearing in some advanced weapons and intelligence systems with multimode logic where the control algorithm prioritizes activities and discriminant selection based on previous experience and decision choice outcomes in each engagement. Self-adapting software for data filtering, multisensor correlation and integration is also appearing in some advanced system concepts. Such systems are inherently more reliable and versatile than single mode systems. These concepts should be employed in camouflage system designs.

Discriminant functions for the detection and classification of targets are central elements in the design and implementation of decision logic for RSTA systems. As sensor technology and signal processing have advanced to unprecedented levels of complexity, the tendency in smart systems design has been to use multidimensional algorithms and collect critical input data during the engagement for the subsequent system decision functions. Thus, the discriminants have become more complex but, perhaps, more susceptible to countermeasures (i.e., camouflage).

In the RSTA/camouflage contest, point detectors can be expanded into sensor arrays. Two dimensional (2-D) and even 3-D functions can be used to represent and resolve target information on both sides. The integration of multisensor data over time with smoothing and tracking filters for all input channels, the sequential and cross correlation and resolution of multiple targets and the use of fine structure in spatial and statistical discriminants are used to enhance discrimination capabilities but with a significant increase in the requirements placed on the system designer to specify what he needs. For example, as the resolution of a target changes from unresolved to resolved (e.g., from MW radar to MMW radar to laser IR) so do the probability distributions governing corresponding target images (e.g., from one-dimensional to multi-variate). Image centroid estimates of target position (linear discriminant) must give way to discriminants involving edge resolution and spatial relationships as well as classification discriminants involving polarization, spatial phase resonance and the statistics of fluctuating target images, all distinctly non-linear. Camouflage has an excellent chance of neutralizing the RSTA under these circumstances.

To provide direction for discriminant logic development, the camouflage system requirements for various missions must be translated as clearly as possible into sensor, signature, signal processing and decision-making requirements for the design application. Specifically, system integration help must be provided for the software design that will implement the detection/discrimination/decision/action response in effective ways.

There are a large number of features/spectra that may enter into the target detection/classification problem. Details on how each discriminant might be constructed are not discussed here, but depend upon each particular design implementation being considered. A system developer will be obliged to select a preferred design approach and then develop the discriminant functions that best suit the requirement. This does not mean as in the example above, that one automatically chooses two-dimensional sensor arrays and real-time image processing rather than much less demanding one-dimensional unresolved target centroids when the latter are good enough. Such design tradeoffs and others must be investigated in the technology base.

D-14 SIGNATURE FIRE STRUCTURE EXPLOITATION (FALSE TARGET SYNTHESIS)

This brief review of camouflage technology base opportunities can provide only an indication as to how these complex technology areas can contribute to future camouflage systems. As noted previously, signature synthesis of friendly targets should be explored in the technology base in terms of conditions, devices, algorithms, and the adaptive approaches needed. Results should provide preferred (even optimal) bases for enhancing false target synthesis and detection, inducing identification/classification errors, clutter enhancement, phase distortion, gate capture, or similar denial techniques. Signature exploitation involves development of countermeasure resistant logic and devices to create the desired signature effects.

Advanced computer capabilities in various forms will underwrite the exploitation of fine structure signatures in the radar, IR, and optical bandwidths. The extremely high computing loads derive from high data rate digital processing, low power consumption, wide band waveform modulation, single chip IC's, and advanced narrow band processing algorithms utilizing VHSIC/VLSIC/MMIC technology.

As computer sophistication increases, the quality and precision that will determine who wins the RSTA/camouflage competition in detecting and classifying targets depends on processing algorithms that may include:

- Pre-processing enhancements (gain, brightness and focus, etc.)
- Segmented image processing
- Feature extraction (up to 100 or more)
- Detection (a decision-making process)
- Validation/classification (a target/false alarm comparative analysis algorithm)

Various techniques such as thresholding, target/background contrast interpretation, target object area, S/N analysis, and adaptive processes useful for target enhancement in segmentation can provide an adequate basis for fine structure exploitation. Physical and practical constraints in system applications on both sides remain to be determined.

D-15 ENHANCED C^3I AND NETWORKING

Until recently, camouflage actions have depended largely on internal or, at most, very short communications links. This may no longer be the case. Increasing RSTA system complexity introduces significant communications requirements between camouflaged targes, response, data exchange and processing points, remote action locations, and command and control nodes. The rapid advances in computer applications for RSTA have challenged battlefield survival of friendly forces and camouflage as a means of improving it.

Camouflage systems concept developments must henceforth address system integration requirements as well as associated requirements for secure communications links. First consideration should be given to optical/fiberoptics technologies, small aperture terminal transponder nets (airborne, satellite), digital processing, and waveform designs as means of avoiding enemy disruption or exploitation of essential C^3 links in future camouflage systems.

Communications link security means avoiding disruption or delay in transmitting/receiving vital information, eliminating insertion of false/misleading information, and maintaining high confidence in received messages. The integrity of camouflage system command and control depends on secure communications.

Technology base programs should be concerned with how to make best use of spread spectrum coding, frequency hopping, bandwidth limiters, adaptive filters, transmitters with high peak power and low duty cycle, precision timing and even possible uses for low sidelobe antennas, adaptive antenna patterns, and agile sensor array scanning. For multiple unit systems, contemplated for camouflage of extensive force deployments over long periods of time, the more complex ground/air/space concepts may use overall overt/covert communication techniques with agile, timed, pulsed signals for effective secure operations. In addition, cooperative monitoring of the EM spectrum may provide means of evading enemy jamming or spoofing.

"Smart" camouflage networks with multi-sensing, multiple response, and advanced adaptive capabilities can themselves function as important elements of modern battlefield C^3I networks. They use as well as contribute information and control for the overall system operation. Geographic dispersal of camouflage, sensors, data sources, data processors, data bases, and command users linked by transmission/receiving elements characterize future "smart" systems. Implementation of such systems is keyed to the usual development in network architectures, protocols, and information processing that allow for fault tolerance, adaptive/distributed control, and innovative function allocation.

Technology base concept developments must consider advanced camouflage concepts along with their sensors, electronics, materials, and software in evolving whatever systems integration is required in the C^3I environment. These efforts can define network structures, trunks, nodes, and terminals and the software required to implement them. Especially useful for C^3I are networks designed to access data bases that may be distributed among various nodes in the extended camouflage system.

Development and integration of technologies to enhance C^3I networks -- in which camouflage may play an essential role -- must deal with integration of overall RSTA surveillance, intelligence, navigation (positioning), communications, and command

data in near real-time. Application of the most advanced computer technology will be essential as an aid in multisensor detection/discrimination of relatively large numbers of targets and in alternative approaches to digital computer architecture for integration of camouflage functions with battle management and planning, a requirement whose importance is only now being recognized.

IFF system requirements are a natural element in the camouflage sensor, signal processing, discriminant logic, and processing requirements described in previous sections. Development of unique passwords, identifiers, and discrimination techniques can provide attractive IFF options for future systems effectiveness.

In the potentially intense signal environment in the modern threat scenarios, camouflage system requirements must be developed to guide realistically the signal acquisition and sorting, response times, CM/CCM signature modulations and power requirements for effective IFF. Availability of extremely capable signal processing and future computer capabilities offer great potential for enhancing camouflage system performance in this area.

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APPENDIX E

EXAMPLE PROBLEM

E-1 INTRODUCTION

This appendix traces a single example system through the development process. This continuity makes it possible to follow step-by-step the process of achieving camouflage for an item during its development. Many items now fielded, or in their final research and development or production phases, must necessarily follow the product improvement route set forth in AR 70-15 to incorporate camouflage. The process for camouflaging these items/systems will follow the same logic and steps that are required for items/systems during development. Therefore, the example is adequate for both cases.

E-2 EXAMPLE SYSTEM

A fictional weapon system was selected as an example through which approach and methodology could be illustrated. The system chosen does not introduce a large array of close range remote sensing system which would add needless complications. A system (rather than a single item) was chosen to bring out operational and ground signature characteristics which are not always associated with single items. Items which exist in large numbers, such as trucks and tanks, are generally found in groups and, as such, present ground patterns and standard operating procedures which must be taken into account in operational camouflage--but which are not directly concerned with individual item design and technical operations.

The fictional example systems will be called "ZEBRA." The following is a brief description of the ZEBRA system:

- Physical Description:

  ZEBRA is a saturation rocket system capable of launching 32, 6-inch diameter rockets single or in rapid salvo. The rockets have a maximum range of 10,000 meters. The launcher is transported on a flat bed truck containing one extra reload forward of the launcher assembly. Additional reloads of four sets are carried on a second carrier, a duplicate of the launcher transport vehicle. The launcher assembly is mounted on a swivel platform to provide rapid reload (average time: 10 minutes) from the second carrier and for vertical launching of missiles that permits firing from tree cover. The mechanism is powered by a central hydraulic pump.

  Current design calls for the use of a draped tarp over both launcher and reload vehicles. The rockets may be fired from the cab in an emergency, but normal firing will be accomplished from a remote position by wire command. Aiming is accomplished by an on-board computer with position location using LORAN. The carrier consists of a standard truck bed with a diesel engine having vertical exhaust to the rear of the cab The carrier is supported and leveled by hydraulic outriggers. Provisions for multiple guidance and warhead packages are included as attachments. Inertial

guidance is normally used, but can be overridden by external coded radio or laser command beam rider on signals from an acoustic or thermal type homing device. Command link communication is by radio.

- Operational Description

  The system is primarily intended as a mobile point source interdiction to inhibit effective mass armored attack, and secondarily to serve as general artillery. In concept, it is intended that a density of 10 ZEBRA firing units will be deployed per type division. All ten units will be attached for administration, protection, and support to a battalion size unit.

  Support and re-supply are provided by standard 5-ton cargo trucks carrying three reload packages of 32 rockets each. A processing and checkout van is used to prepare the rockets as received from depot via a field distribution point. The communications gear and extra remote firing units are also carried in the van. The van is standard. A crew of eight is required and is transported in the firing, reload and checkout and resupply vehicles. Other life support, plus security, is to be provided by the unit to which ZEBRA is attached.

E-3 STEP 1 -- CAMOUFLAGE NEEDS DETERMINATION

The ZEBRA system appears in the latest camouflage sensitive list. The Project Manager of ZEBRA is cognizant of this fact and has initiated action within his staff to comply with AMC Pamphlet 70-2.

E-4 STEP 2 -- SYSTEM DESCRIPTION

The ZEBRA system has passed through its concept exploration/definition phase and is now in its concept demonstration/validation phase. It is a high cost system under development by a project manager. An approved O&O plan exists for this system. A ROC has been drafted for it, but has not been finalized. A hardware mock-up has been produced and a development plan outline was completed. This point in the life cycle has been chosen to illustrate the advantages to be gained by giving early consideration to the camouflage problem.

E-5 STEP 3 -- THREAT ASSESSMENT

The Foreign Intelligence Office (FIO) was requested to augment the existing general threat contained in the development plan to enable a detailed estimate of the reconnaissance, surveillance and target acquisition (RSTA) threat posed to the ZEBRA by the threat forces during the period 1990-2000. To assist in this endeavor, the FIO was provided with the following information:

- Current O&O plan and draft ROC for ZEBRA.
- General threat from the latest version of the ZEBRA development plan.
- System description.
- Operational concept.
- Scenario and world areas of concern.

The FIO was advised that their RSTA information would be of greater value if it could be summarized as follows:

1. By spectrum and spectral region as conventionally used (e.g., UV, Visual, Near IR, etc.). The capabilities deemed most critical for each spectral region include:

   - Sensitivity bandwidths.
   - Spatial resolution.
   - Contrast resolution.
   - Spectrazonal aspects.

2. A series of graphs depicting the likelihood of effective observation occurring by direction and range within a vertical plane and using a probability of 0.95 and 0.5 when considering conditions of weather, terrain, frequency of observation (number of encounters with sensors), and other factors which may be deemed important, such as the likelihood of correct detections resulting from analysis of sensor acquired data. Three condition levels are desired: optimum, nominal, and poor.

   The term effective observation is used to indicate that the target is within effective range and view of sensors utilizing he particular spectral regions involved and that the time of observation, platform speed, and other factors are satisfied. Enumeration of specific foreign surveillance devices and systems is unnecessary and undesirable.

3. An estimate of enemy capability to take offensive action against the ZEBRA system once it has been detected. This estimate should take into account both an ability to locate the system and its components, and the availability of suitable attach mechanisms and fire direction methods (TV, laser, visual, etc.).

The FIO response provided the data requested. A further analysis was conducted by the project manager's staff and led to the following findings:

1. The battlefield surveillance for targets of the ZEBRA type operating in the proposed geographic areas of Central Europe and the Middle East during the 1990-2000 time frame is expect to be only moderately improved from the current capability. System utilizing laser and holographic elements in remote sensing and analysis are expected to make the greatest progress and offer the greatest potential for any dramatic increase in effectiveness.

2. As currently proposed, the ZEBRA system does not appear to be susceptible to detection by nuclear, seismic or chemical monitoring and these have, therefore, been excluded from further consideration. The remote sensing systems most likely to be a threat to ZEBRA include aerial photography, direct aerial observation, and infrared using both the 3-5 and 8-14 micron windows with FLIR the most critical system in attack situations. SLAR is expected to be only moderately effective and airborne MTI will be a problem only during convoy movement. Direct view light intensification systems will augment night attack capability, especially from the air.

3. Estimates of effective observation occurring for each type of remote sensing considered a threat to ZEBRA are provided in a series of figures. Observation effectiveness refers to the combination of expected frequency that the target will be subject to a particular type of remote sensing, time of day, time available for observation, and platform speed. The estimates are presented as a likelihood of effective observation versus range and direction in relation to the ground plane. Three graphs are used for each remote sensing type to present the effect of optimum, nominal and poor conditions affecting observations in Europe and the Middle Eastern geographical areas.

4. Offensive action taken by an enemy to neutralize the ZEBRA system would most likely take place during the early stages of a general offensive because the ZEBRA is essentially defensive in nature and presents a threat primarily against vehicular targets within ranges of 8,000 meters. Reaction time from detection to attack can be very short for visual acquisition where rapid data links from the sensor to the fire control center are present. A vectored missile or aircraft attack using a form of homing munition are within the capability of military forces of consequence.

5. An approximate (most likely) attack on the ZEBRA system will include (a) fighter aircraft (with FLIR) armed with rockets, bomblets, cannons and napalm, (b) artillery of a conventional sort, and (c) stand-off guided missiles.

Information available indicates that the kill probability for targets of this nature once detected and under attack by any of the above on a single sortie basis is between .03 and 0.5 Moderate damage probability is between 0.2 and 0.8.

The following major detection and identification cues associated with the ZEBRA system in combat have been derived from analysis by intelligence and image interpretation personnel:

A. Preparation and Training Mode

1. Surveillance

(a) An obvious and positive cue for identification is the launcher rack mounted on a large flat bed truck.

(b) The association of the three large vehicles and a van.

(c) Signature steps in the checkout of missiles and other training activities.

(d) The size and nature of the system will restrict hiding to deep defiles and large buildings. The exposed nature of the equipment allows for significant solar heating during the day and long-time cooling at night. Exhaust engines and generators are unshielded and detectable.

(e) Signature details include the cable to the remote firing position; outriggers; support on launcher; ranging and communication antenna on van and the illogical context of having large flat bed cargo type trucks so close to FEBA.

(f) Vehicles are susceptible to SLAR detection but are not readily identified. MTI detection on the convoy is likely.

(g) There are several electronic emissions during checkout and training which provide detection and identity cues.

(h) There is little concern for direct ground-to-ground observation for this system.

(i) Surveillance observation will most likely be from photography, DLIR, and visual sighting.

2. Target Acquisition

(a) When in bivouac, the system presents an acceptable aerial target. When mixed in with support unit elements to which ZEBRA is attached, and using a normal amount of operational camouflage discipline, the probability of attack on ZEBRA is no greater than for any other military equipment in the same area.

(b) When in a stimulated fire mode for training, the same cues are present as indicated in "C" below, "Fire Mission Siting and Installation Mode."

(c) Attack would likely be from fighter bomber aircraft using bombs, rockets and cannon, or from long range auxiliary. In this mode, the system does not present a sufficient threat to invite attack by guided bombs and other high cost sophisticated weaponry.

B. Convoy Mode

1. Surveillance

(a) In this mode, detection is assured when moving and will be a function of the number of times the system falls within the field of view and resolution of sensors used.

(b) Identity cues are the associated vehicles in number, kind and context of cargo carrying vehicles near FEBA.

(c) No specific signature cues are present except electromagnetic emissions. These are characteristics of similar vehicles and, therefore, will be of little significance until associated with other evidence.

2. Target Acquisition

(a) If a part of a larger contingent of vehicle traffic, there is little reason for ZEBRA to be singled out for attack. Attack is, therefore, reduced to chance unless surveillance has identified ZEBRA and is attempting to eliminate it under conditions where it is most exposed and vulnerable.

(b) Attack will be most likely from fighter bomber aircraft on a target of opportunity basis and by visual or FLIR acquisition and aiming using bombs, rockets and cannon. Stand-off helicopter attack by guided bombs is considered a low threat in this mode.

(c) Ambush attack by pre-registered long range artillery aimed at a specific road point for example, and controlled by forward observers or radio linked pre-positioned sensors is possible, but not unique to this system. The system is large enough, however, to invite such fire if the enemy coverage is on a selective basis.

C. Fire Mission Siting and Installation Mode

1. Surveillance

(a) Firing positions may be utilized for several days prior to executing a fire mission This mode poses an immediate threat to an enemy and one which will be high on his list of priority targets as a serious impediment to any attack by him.

(b) During siting, the likelihood of detection (convoy mode) will be high and nearly a one-to-one relationship to sensor coverage. Detection likelihood will decrease once the system is installed in an acceptable site and using a reasonable level of camouflage discipline during installation and while in place. If the position is in trees, defile or cluttered terrain, this detection likelihood will be further decreased.

(c) Tracks from a road net or across open terrain will increase the likelihood of detection and aid in identification.

(d) Once installed and quiet (non-operating), detection through photography and downward looking FLIR are the principle threats.

(e) A major cue will come from the need to expose the launcher for firing. This exposure need be for only a very short time, however.

2. Target Acquisition

(a) If the enemy is not planning an early engagement, attack will most likely be that of targets of opportunity.

(b) Assuming the enemy planned action and a serious effort to find all targets likely to impede his progress, surveillance will have located and identified this system as a serious potential threat and will direct an attack against it.

(c) Exposed or hidden from view, such an attack will attempt to destroy the launcher as the most vital point in the system. Attack may be directed against an area position only, or in this mode, sophisticated weapons may be considered warranted.

(d) Ground pattern and dispersion of equipment controls likelihood of hits in this instance.

D. Firing Mode

1. Surveillance

(a) In this mode, all the cues are present that existed in the Fire Mission Siting and Installation Mode. Siting and installation plus the action of final positioning and direction of the launcher followed by flash, smoke, dust, sound and electromagnetic impulses associated with firing and controlling the missiles together with communications from fire direction authority causes high probability of detection.

(b) Identity and signature cues include flash analysis, salvo fire, sound analysis and characteristic flight patterns; all detectable and capable of being used in a signature sense.

(c) The launcher and storage racks will produce a high radar cross section to SLAR and, except in a heavily cluttered background, will produce high detectability.

2. Target Acquisition

(a) The above signatures can be used to locate the system within a reasonable CPE (circle of probable error) through triangulation, MTI radar, and IR backtracking systems.

(b) The same attack methods are likely as were used for previous ZEBRA system modes plus the added potential that IR seeker homing is now possible. Direct air attack is still most likely.

E. Post Firing Mode

1. Surveillance

(a) The additional detectable emissions available for a short period after firing are the thermal and blast effects on the surround terrain and launch vehicles.

(b) The reload operation after two salvos requires bringing two large vehicles side-by-side which increases the target cross-section to all sensors. This condition exists for only a short time but tracks covering a reasonably large area will provide a signature.

(c) This activity and ground pattern presents a sizeable identity cue.

2. Target Acquisition

(a) The additional cues available in this mode, the need to move vehicles, etc., together with location data obtained by the enemy from firing, will cause the system to be more detectable and more likely to be attacked.

(b) Assuming the firing has caused damage to the enemy attack, the neutralization of the ZEBRA will be urgent, and may result in the expenditure of more resources to render ZEBRA ineffective. Attack against this mode will probably be an area coverage through conventional artillery or multiple sortie air attack.

E-6 STEPS 4 AND 5 -- ANALYSIS OF WORTH AND COST

The threat analysis indicated that for targets of this sort, there is a high likelihood of enemy detection and effective counteraction which would seriously affect the survivability of the system. The example presumes that staff level communications have been maintained between all parties concerned.

As indicated in the text, two parallel actions are initiated at this point based upon the findings of the threat analysis. The first is that of conducting a military worth analysis (see Section 4) using several assumed levels of camouflage capability (and other countermeasures) ranging from the assumed baseline of the current system to a level of mission capability and survivability that produces a significant positive change in outcome of engagements played. The second and parallel action undertaken is that of determining the cost of the ZEBRA system deployed as operationally intended and subjected to the life cycle resource needs.

The model studies were accomplished and generally confirmed the detection and identity cues (perceptibility) indicated by the threat analysis. These studies provided quantifications of expected ranges and search times likely under a set of conditions and within the scenarios set forth against the threats of visual acquisition, photography, IR (DLIR and FLIR), SLAR and MTI radar where the threat analysis indicated they would be a threat.

In order to quantify, if possible, the military worth of ZEBRA camouflage, the combat model, which was used to investigate the firepower and maneuver options of the ZEBRA system (such as optimum rocket performance, number of rockets per reload, number of reloads available in the battery, number of vehicles in the battery, number of men in the battery, warhead lethality, employment doctrine, cross country mobility, reload time, resupply time ...), was used to investigate the effect of camouflage on the outcome of the battle played in the combat model. This model was modified to be able

to account for ZEBRA camouflage and enemy attack aircraft. The attack aircraft was given the capability of a FLIR target acquisition system similar to that identified as the primary threat in the threat assessment.

Since ZEBRA was designed as a defense against massed armor attacks, the MOE chosen was the number of Red tank casualties during the battle. ZEBRA survival time after firing the first salvo was considered as a MOE, and survival time certainly would have a strong effect on the outcome of the battle, but it is not as good a measure of the outcome of the battle as is the number of tank casualties.

The military worth of ZEBRA camouflage will be judged in a simulation of an attack, by a Red tank regiment (98 tanks, 20 BRDM's, 6 ZSU-23-4 gun systems, and 6 ZSU-S7-2 gun systems), against a Blue defensive force of 20 tanks, 20 TOW launchers, 40 DRAGON launchers, and one ZEBRA system. The Blue force is in a prepared defensive position and each side is aware of the equipment and capabilities of the other. The combat model has two terrain sub-models, one representing Central Europe and its prevalent weather condition, and the other representing a Mid-East desert region and its prevalent weather.

Since the target acquisition threat played in this combat model was a FLIR mounted on an attack aircraft, the MOP used was that which would predict the behavior of the attack aircraft. The modification to the combat model, which included the camouflage and attack aircraft, described their interaction in terms of slant range. Slant range data was used as a decision rule; if the flight path of the aircraft is such that the ZEBRA is in the field of view of the aircraft, then the probability of target acquisition associated with the ZEBRA-to-aircraft range will decide whether or not the ZEBRA is acquired, if acquired, other program sub-models determine whether the aircraft can deliver damaging fire onto the ZEBRA.

The results of the military worth analysis indicated that, in all cases investigated, the Red force overran the Blue defensive position. When the uncamouflaged state of ZEBRA was played (acquisition range of 4,000 meters), there were 20 Red tank casualties. When an acquisition range of 2,000 meters was played, 25 Red tank casualties occurred. And when a acquisition range of 1,000 meters was played, 30 Red tank casualties occurred.

The outcome of the model and field tests of the surrogate components has resulted in the following findings:

At the Eastern test site, the surrogates, in an open area, were detected within 15 minutes and positively identified within 18 minutes. Acquisition ranges, with pilots cued to the position, were between 4.8 kilometers and .8 kilometers with the mean at 3.4 kilometers. Deployed within wooded terrain, the initial detection and positive identification times increased to 30 minutes and 35 minutes (mean). Acquisition ranges decreased to 1.3 kilometers at low altitudes with no reduction in overhead viewing range.

E-7 STEP 6 -- DETERMINE INITIAL GOALS

Assessment of these combined results of the military worth analysis and the initial perceptibility study revealed that:

1. The system has no inherent means of physical self-protection other than operators using rifles and Redeye.

2. ZEBRA is most valuable to the defense at the time of enemy armor attack and the system is most susceptible to detection and attack (identification and location) at the time of active firing with the second most serious period occurring during the post firing reload mode.

3. The estimated time to detection varies from 15 minutes and 30 minutes, and the detection range will be on the order of 5000 meters ± 1000 meters for attack and the most probable attack will be from low flying aircraft using FLIR or a terminal FLIR guided rocket. It is unlikely, although possible, that laser illumination would be utilized against this target.

   Results of the parametric study shows that if the system is to be militarily useful, it must have a target acquisition range of 1000 meters or less against the threat aircraft FLIR system.

The following camouflage goals were recommended for inclusion in the ZEBRA requirements document:

1. The target detection range of the ZEBRA be 1000 meters or less against the threat FLIR system.

2. The identity cues (indicated in Appendix A-2), which define the system as ZEBRA, be hidden, shielded or eliminated.

E-8 STEP 7 -- SELECT TECHNIQUES TO REDUCE VULNERABILITY

Based upon the results of countermeasure studies relating to ZEBRA, and the requirement to meet the goals indicated in the ROC, the following camouflage was proposed for inclusion and use by the ZEBRA system.

1. Equip both the launcher and reload vehicles with a rapid action accordion type bow and tarp disguise in lieu of the current tarps only. This disguise will collapse forward along special tracks on sides of the truck bed to a point forward of the auxiliary generator-pump. Incorporate wire mesh into the tarp to reduce the RCS resulting from the launcher and carrier.

2. Replace the van with a standard combat cargo truck of appropriate size carrying a prefabricated operations shelter beneath the standard bow and tarp.

3. Assign standard camouflage screen modules as required for each truck in the system to utilize the existing QCD for exposing the launcher for firing on short notice. These screens are to be employed primarily in concealing firing positions prior to initial firing and to prolong detection-identification after the missiles are launched. Local materials and camouflage discipline are prescribed to increase concealment for longer times spent in one position.

4. Insulate and shield the exhausts, engine compartments, and launcher erector to meet reduced FLIR detection ranges.

5. House the auxiliary generator and compressor in a thermally shielded compartment using combined radiative and air cooling with an overhand awning plus air cooled louvers to deflect cooling air away from nearby foliage.

6. Cover the launcher and rocket rack with shaped metal mesh or screen to deny SLAR the large RCS which results form these racks.

7. All vehicles will be pattern painted and equipped with external windshield, headlight and side window shields incorporated.

8. Communications antennae will be collapsible into a recess during non-use.

9 Develop and incorporate a metallized fabric flash shield for deployment around the launcher in its vertical launch position.

10. Provide decoy flash and sound generators for synchronized use at time of launch. Provide exothermic heat generators and corner reflectors to confuse FLIR and RADAR search and attack. These items are to become a part of the operational SOP and a part of the ZEBRA TO&E.

11. Incorporate a fluid tank, hoses and appropriate spray heads to spray the launcher and immediate area with a cooling fluid.

12. Develop (or adopt) a rocket dispersed thermal and radar screen in cooperation with appropriate EW organizations to deny accurate backtracking. This screen, when emplaced above the ground clutter height and combined with the vertical launch feature and joined with the decoys in "10" above, are expected to sufficiently delay location of the ZEBRA for a time exceeding that indicated as necessary in the worth analysis.

E-9 STEP 8 -- INCORPORATE CAMOUFLAGE INTO THE DEVELOPMENT PROCESS

The twelve actions described in paragraph E-8 must be incorporated into appropriate documents, resources obtained, and test activities arranged to assure the initial camouflage goals are realistic and achievable. These activities are discussed in the following paragraphs.

The twelve camouflage items proposed for the ZEBRA system were placed into three levels of developmental need.

- Existing and available equipment/technology.
- Simple modifications to ZEBRA hardware.
- Solutions requiring further development.

The camouflage items which make use of existing and available equipment (Accordion-bow top; Cargo truck/shelter; Camouflage screens; Pattern painting/glass shields) required simple changes to the Basis of Issue Plan (BOIP) and eventually the Table of Organization and Equipment (TOE) of the ZEBRA firing battery.

The items which require modifications to the ZEBRA hardware (Exhaust and engine shields; Auxiliary generator, erector insulation/shielding; Metal mesh cover for launcher/rocket rack; Collapsible antenna; and Cool down spray system) were incorporated into the system Technical Data Package (TDP) and further into the production contract. Therefore the Cost and Effectiveness Analysis (COEA) and the Integrated Logistics Support Plan were reworked to include these items.

The remaining three items which will improve the ZEBRA system required some form of development (Vertical launch position flash shield; Development of visual, acoustic, IR and radar decoys; and a Counter-counter battery IR/Radar screen). The latter item required its own developmental stream while the first two became pre-planned product improvements (P^3I) to the ZEBRA system. The O&O Plan and the ROC were modified to accept these new additions to the system.

Funding for the camouflage items was made an integral part of the overall cost structure of the system. The enhanced survivability brought about by the camouflage items was reflected in an updated COEA.

The Test Evaluation Master Plan (TEMP) was modified to incorporate the testing of the effectiveness of the changes in meeting the camouflage goals.

E-10 STEP 9 -- FINALIZE PERFORMANCE GOALS IN REQUIREMENTS DOCUMENTS

The twelve camouflage actions chosen for ZEBRA were then evaluated for their potential to achieve goals set forth in Chapter 6. In some cases it was possible to increase the initial goals, and in other cases the initial goals had to be reduced. After evaluation the revised goals were finalized into the ROC under paragraph 5, Operational Characteristics.

It was decided that the target acquisition range goal for Threat FLIR systems should be 800m rather than 1000m. The identity cues which define the system as ZEBRA cannot all be "hidden, shielded or eliminated" as set forth in the initial goals. The goal was therefore changed to "hidden, shielded or significantly reduced".

E-11 SYSTEM DEVELOPMENT

The full scale development of the ZEBRA then took place. The evolution of the ZEBRA in this stage of development took several years. The incumbent Project Manager (PM) was reassigned and his successor included in his initial orientation process a complete familiarization of the camouflage requirements. The new PM stayed abreast of camouflage needs as the maturity of the system evolved. A significant part of the evolution was the concurrent testing of components, incorporating camouflage aspects whenever possible in the testing.

E-12 STEP 10 -- TEST AND EVALUATE CAMOUFLAGE PERFORMANCE TO MEET REQUIREMENTS STATEMENTS

The proposed modifications to improve camouflage were incorporated into the early testing. Early user tests and experimentation helped define and refine the exposure of the ZEBRA system to Threat target acquisition systems. Technical

Feasibility Testing (TFT) and Operational Feasibility Testing (OFT) accomplished before Milestone I focused on major technical and operational issues for the ZEBRA system. Camouflage concerns were addressed in a parallel stream as shown in Figure 1-2.

As initial camouflage goals emerged, they were incorporated into the O&O Plan and the draft ROC. The applicable camouflage techniques selected in Step 7 were then inserted into the TEMP and included in the Developmental Testing (DT).

After the camouflage goals were incorporated into the ROC and full-scale development produced a ZEBRA system, the Production Proveout Test (PPT), Pre-production Qualification Test (PPQT), and the Operational Test and Evaluation (TO&E) included camouflage test items.

The Project Manager asked for assistance from Belvoir Research and Development Engineering Center's Countersurveillance and Deception Division. The BRDEC support included assistance in scale model testing using the Radar Arch, as well as information on ways to use other available test facilities (see Appendix C). However the main thrust of testing ZEBRA camouflage measures was the incorporation of camouflage test items into the larger tests conducted on the complete ZEBRA system in its operational mode.

The tests results showed that the camouflage goals set forth in the ROC were achievable so long as the ZEBRA crews performed the set-up and operations with care. The system was fielded within the normal development time frame and deployed initially to the European theater.

APPENDIX F

THREAT RSTA SYSTEMS

F-1 INTRODUCTION

The purpose of this appendix is to set forth a more detailed discussion of threat reconnaissance, surveillance and target acquisition (RSTA) capability. Included is an indication of technological trends which the developer must consider in an assessment of actions needed to enhance the survivability of his evolving item/system.

F-2 OPERATIONAL CONSIDERATIONS

Among modern combat forces, camouflage in various forms is a natural part of basic military tactics. Effective camouflage prevents enemy sensors from detecting, recognizing, identifying, or locating critical battlefield operations. It prevents enemy sensors, particularly those associated with high-lethality, hit-to-kill weapons, from effectively engaging friendly targets at advantageous attack ranges. The modern battlefield environment -- with the increasing variety and capability of combat reconnaissance sensors -- requires increasingly flexible and technically advanced camouflage. The size and complexity of modern combat and combat support systems to be concealed amplify and greatly complicate this problem.

Enhancing battlefield survivability through the combined effects of CCD can provide greatly reduced susceptibility to detection/recognition/identification/location and acquisition of tactical targets Camouflage can provide a combat force multiplier and force extender that contributes to achieving an edge for the user. Against the multitude of battlefield threat sensors, camouflage against the human eye is a common denominator. The incidence of engagement between friendly forces and the opposing RSTA using human eye, aided or unaided, is so much higher than any other type of encounter that the camouflage doctrine and tactics against these ubiquitous sensors must be considered first and foremost. Tactical intelligence collection using the unaided eye or using visual aids such as binoculars, telescopes, image intensifiers, low-light-level high resolution TV or any of the night vision devices is considered the most important category of military intelligence for ensuring the success of combat operations at the tactical unit level (i.e., division level and below). Such collection efforts are normally conducted to obtain information regarding terrain, weather and projected combat operations as well as enemy targets, dispositions, and readiness. The Soviets, for example, define reconnaissance as the collection of intelligence information about the character of activities, disposition, location, composition, numbers, armament, preparedness, and intentions of an opponent. They recognize that such reconnaissance operations will be met by enemy countermeasures and deception operations. Therefore, diverse collection means are employed to obtain the information and these various collection means are allowed to overlap. Soviet reconnaissance is the responsibility of the commanders and staffs of units/subunits at all combat levels.

In the Soviet forces, RSTA is organic to all combat units and although units above company level generally perform most of the target acquisition, RSTA systems are organized so that target acquisition functions and capabilities can be passed

expeditiously between echelons. Reconnaissance units may operate over extensive, overlapping areas and provide timely, accurate information for combined arms, OMG and deep strike operations. Addition of advanced materiel for electronic, chemical, radiological or engineering purposes increases unit combat effectiveness and enhances Soviet combat doctrine which relies on speed, maneuver and massed fires.

However, it should be recognized that if only the technical resolving powers of remote sensing systems are considered in an environment <u>most favorable to sensors</u>, it would indeed be a grim world for those depending upon camouflage. All targets of interest would soon be seen and destroyed. In practice, this does not happen because of many factors which complicate the sensor performance such as clutter.

There are many circumstances which restrict the performance of RSTA sensing systems in field situations. In combat, these circumstances tend to multiply and magnify even more. It follows that camouflage is usually more successful in combat than in planned field tests.

It should also be noted that each sensor is associated with a platform which supports, positions, and directs the sensor. A soldier is the platform for the eye; a vehicle is the platform for a mobile radar, and an aircraft/drone/satellite provides a platform for FLIR, SAR or aerial cameras. The performance of the sensor is dependent in part on the characteristics of the platform. The platform has to place the sensor within effective range of the target and must position the sensor within the field-of-view and line-of-sight of the target. The platform location determines the direction from which the target is viewed (ground mounted sensors view the side aspects of a target; aerial sensors view the overhead aspects. The speed or vibration level of the platform must not be excessive or the image will blur.

The Soviets, and others, clearly recognize the value of the human observer as a primary source of information in the RSTA organization. They acknowledge that electro-optical systems are excellent for detecting specific targets. Both air and ground photography are widely used and, like other RSTA assets, are correlated with intelligence obtained from other sources. Other RSTA sources include radio intercept to determine message content and method of transmission, radio-DF to locate enemy transmitters and headquarters, and sound ranging for weapons location. Active and passive radar, thermal and imaging IR and C^3I to control, analyze and disseminate information complete the overall organization.

The world-wide threat to camouflage reflects the low, medium and high levels of RSTA development and deployment among potential U.S. opponents. The primary sources of change will be the continuing upgrading of current capabilities through technical means, expended C^3I organization, and doctrinal adaptations to exploit improved weapons systems. The high level threat represented by the Soviet forces will also upgrade their already formidable radio-electronic combat (REC) capability with RF weapons and laser weapons.

Future RSTA operational capabilities can expect to see long-range, very versatile drones and RPVs, sophisticated electro-optical, radar and millimeter wave sensors, advanced image intensification sensors with digital processing in forward areas, and vastly improved C^3I for systems integration of the sensor threat to camouflage. Emerging battlefield sensor operations, even at the lowest levels of RSTA will gain some advantage in revealing U.S. weapons, equipment and command centers. Soviet

reconnaissance systems already fielded present a grave threat to U.S. camouflage and future widespread deployment of precision guided munitions (PGM) by the Soviets and other regional (medium level) powers or anti-U.S. (low level) forces will significantly increase the threat.

F-3 GROUND BASED THREAT

Tactical doctrine for ground force operations requires detection, location and identification of tactical targets under all anticipated battlefield conditions of weather, visibility, enemy action, or friendly missions. A major threat to camouflage systems deployed to cover or conceal friendly targets will be the reconnaissance elements, ground sensor systems, and the intelligence processing systems comprising the RSTA employed at all levels of operational forces by the enemy ground force commanders. These systems are intended to obtain timely information on both the terrain and the opposing forces, their strength and disposition, and their intentions in forthcoming operations.

Main targets of tactical and operational intelligence collection will include camouflaged critical/sensitive targets such as nuclear-capable units, air defense units, firepower (artillery, armor and tactical air), logistics/supply centers, and C^3I centers. Depending on the situation scenario, the main targets may instead constitute ground combat force elements (attack, defense or reconnaissance modes), tactical strong points that are unique to local/regional situations or even specialized ground forces with unique special purpose missions such as deep strike units or special operations forces. The character of the threat obviously can vary a great deal depending on the targets being sought and this fact complicates the camouflage requirements. For purposes of this Guide, we will assume the threat will be for the most part Soviet or at least Soviet supported client states and combat forces. The threat attributable to the diffusion of western technology into regional and third world forces will be noted as well.

F-3.1 Troop Reconnaissance.

The oldest and still most widely used techniques for gathering battlefield intelligence is to exploit the visual capabilities of human observers at every possible point of contact with the enemy. It is conventional doctrine in nearly every armed force to utilize human patrols for gathering visual intelligence in every area of interest on the battlefield. The frequency of encounter with camouflaged targets with human observers is likely to be many times higher than that experienced with any other sensor or intelligence-gathering device. Hence, the first order of business for camouflage is always to counter the visual threat.

The human eye is the most effective means for detecting, recognizing, and identifying targets because of the intelligence and analytical capabilities furnished by the brain and because of the superior resolution capability, field of view, and dynamic range. The eye has an approximate angular resolution of 1 to 3 minutes (0.3 to 0.9 milliradians), a field of view of 120°, and a dynamic range of nine decades of illumination (10^{-6} to 10^{3} candles per square meter). These are combined capabilities which are seldom matched by any other sensor.

Under certain controlled conditions, the human eye will respond to radiant energy from the near-infrared to the near-ultraviolet, but the visible spectrum is usually considered to extend from 0.38 to 0.78 microns Variations in wavelength are manifested by changes in color (i.e., the violets are at 0.40 microns, blending into the blues at 0.45 microns, greens at 0.50 microns, yellow-orange at 0.60 microns and reds at 0.63 microns and longer). The peak response of the human eye occurs in the yellow-green band (0.555 micron for a light adapted eye and 0.515 for a dark adapted eye), a fact of obvious importance to a camouflage system developer.

Whether or not a target can be detected by the eye depends upon many factors. An indication of the complexity of this problem and a partial solution to the practical estimation of the visual range is given by the nomogram in Figure F-1. Here, the visual range is related to: The area of a target (resolution considerations), the luminance-contrast between the target and the background (sensitivity considerations), the visibility or the meteorological range of the atmosphere, and the luminance of the background.

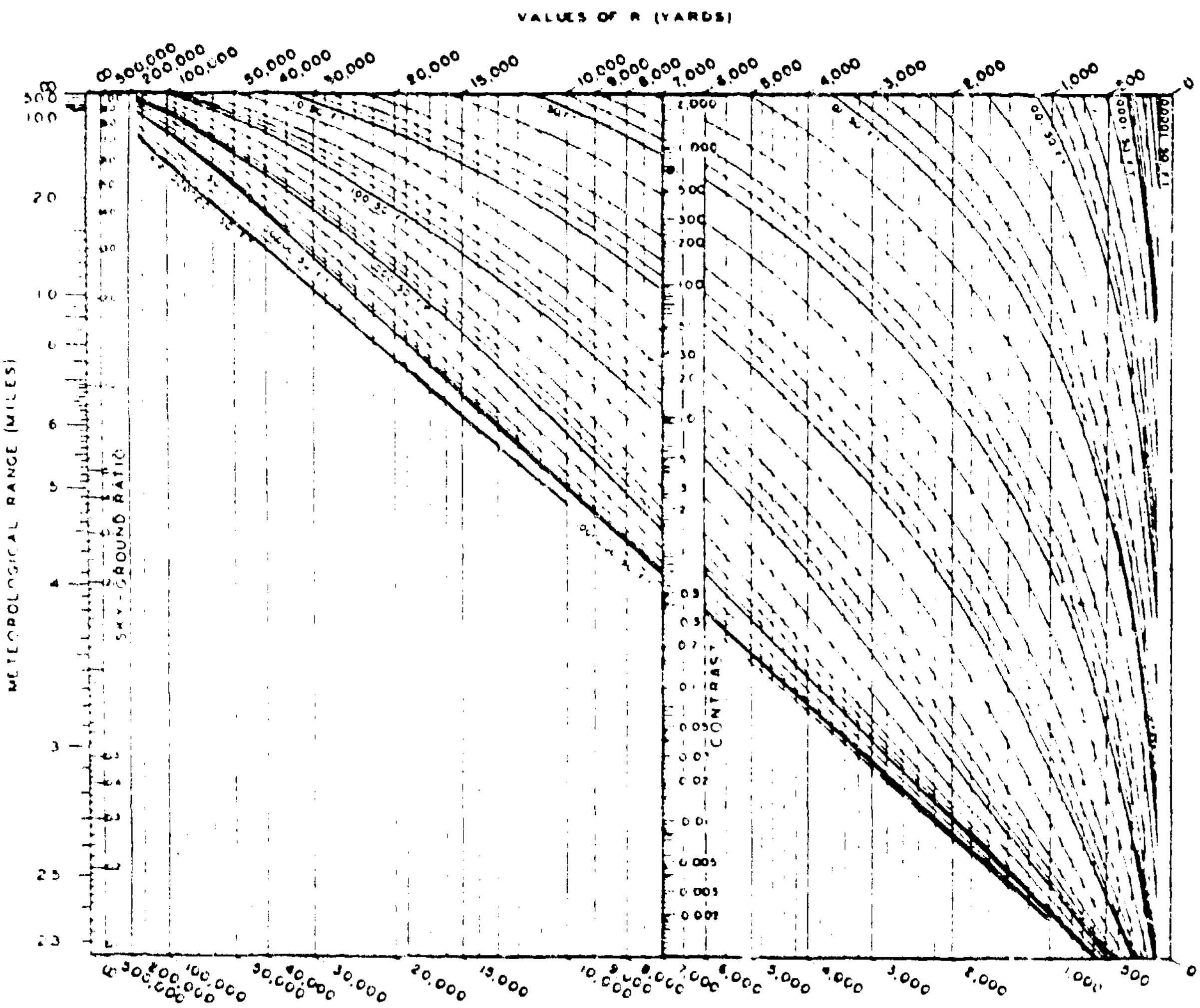


Figure F-1 Sighting Range in Yards of Circular Objects on the Ground, Seen from the Air in Full Daylight, Based on the Tiffany Data for Circular Targets, at a Probability of Detection of 95 Percent.

The luminance-contrast, C, is defined in terms of luminance (brightness) of the target, T, and of the background, B, by the equation:

$$C = (T-B)/B = (R_T - R_B)/R_B$$

The contrast ranges from -1 for a black target on a white background to large positive values for bright targets against a dark background. Contrast may be measured by a photometer or may be estimated from knowledge of the reflectance, R, of the target and of the background. Contrasts greater than 2 to 5 are unusual unless the target reflects sunlight specularly or the background is very dark.

The luminance of the background is taken into account by the sky-ground ratio, the luminance or brightness of the background relative to the sky. Typical values are given in Table F-1.

Table F-1. Typical Values of the Sky-Ground Ratio.

SKY CONDITION	GROUND CONDITION	SKY-GROUND RATIO
Clear	Fresh Snow	0.2
Clear	Desert	1.4
Clear	Forest	5
Overcast	Fresh Snow	1
Overcast	Desert	7
Overcast	Forest	25

Figure F-1 strictly applies only to solid, one-color, circular targets. In general, the more deviation there is from a circular shape, the higher the contrast needed to detect a target of the same area.

As an example of the use of Figure F-1, determine the detection range of a 10 square foot target, reflectance 0.7, against desert soil, reflectance 0.21, under a clear sky with a meteorological visibility of 30 miles and a sky-background ratio of 1.4. The contrast is given by:

$$C = (0.07-0.21)/0.21 = -0.67$$

The first step is to draw a straight line from 1.4 on the Sky-Ground Ratio scale through 0.67 on the Contrast scale. The intersection of this line with the right hand edge of the nomogram establishes a turn point. Next, draw a second line from the turn point to 30 on the Meteorological Range scale. The intersection of this second line with the curved line representing 10 square feet occurs at 4200 yards on the Range scale. Therefore, the range for 95% probability of detection is 4200 yards.

This nomogram is also useful for estimating what cannot be seen at a given viewing range (e.g., visual decoys need not display surface features which cannot be seen). This nomogram can also be used to estimate the minimum area that can be detected and surface features small than this will be detected with less than a 95% probability.

This attempts to explain, at least in part, the basis for visual target detection reflects the significance of troop reconnaissance at every level of threat. At the lowest threat level, visual means may be the only technique available. At higher threat levels, additional sophistication in threat sensors in troop reconnaissance will involve sound/flash detection, electro-optical instruments, radar and various communications and signal intelligence techniques.

The importance of timely, accurate, reliable and continuous battlefield intelligence gathering has increased to such an extent in contemporary warfare that troop reconnaissance has become one of the priority missions (e.g., Soviet ground reconnaissance operations). Special forces up to battalion size have been dedicated and trained to perform these missions. Whether large or small, these ground reconnaissance teams are equipped with the latest SIGINT, COMINT, radar, RF, electro-optical, EW or weapons suites and are supported by ground and air units at all organizational echelons. Such reconnaissance forces, especially long-range teams, represent unique threats to key camouflaged targets or fixed installations including deep-strike camouflage critical/sensitive targets in rear areas.

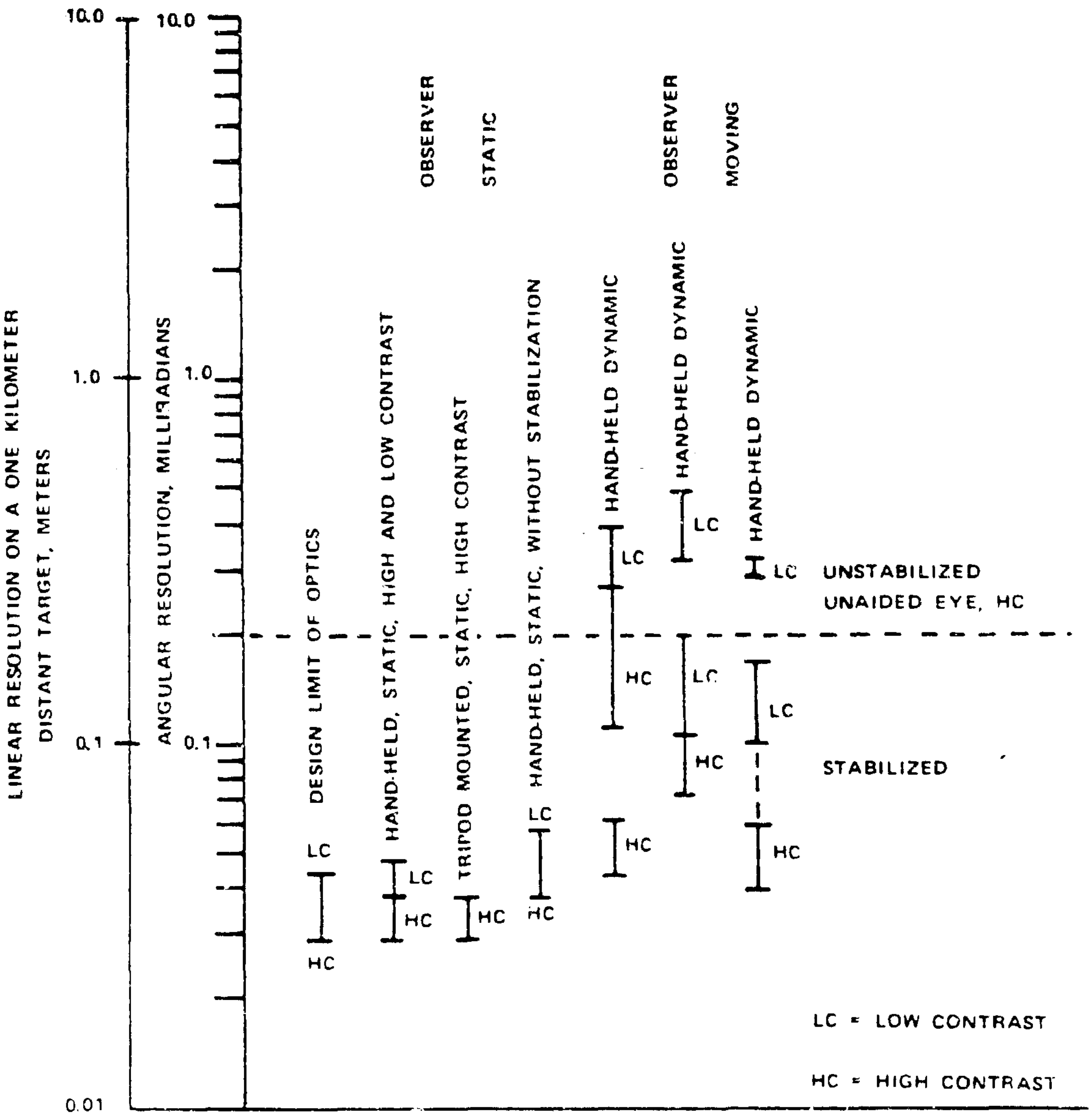
F-3.2 Visual Assisted RSTA.

Visual assistance is being provided for RSTA operations in passive modes that offer maximum surprise at minimum risk. At least 20 countries produce this type of equipment for the world market. Latest generation devices significantly increase the RSTA threat to camouflage and increase the demand for improved camouflage capabilities.

There are a number of sensing devices which enhance the ability of the eye to detect and identify targets. Devices such as binoculars and periscopes, image converters, image intensifiers (II), and LLLTV are representative of this class. These devices extend the observer's viewing range by forming an enlarged image of the target at the observer's eye, by extending his vision into the near-infrared (to 1.0 micron) as well as to illumination levels far below the normal vision capabilities. They also allow the observer the capability of not looking at objects in front of or behind the target.

Several developments have had a significant impact on visual enhancement devices such as binoculars and periscopes: (1) the application of anti-reflection coatings to optical surfaces, and (2) the use of active optical elements to stabilize the observed image in hand-held devices. Devices with coated optics have more light transmission and less veiling glare than with uncoated optics of equivalent design. This extends the observer's range into lower contrast and illumination levels. Active elements stabilize the image at the observer's eye by optically compensating for slight angular motions of the optical device caused by hand tremors and platform vibrations and enable observers to use higher magnifications and to observe from moving platforms. These developments are positive factors in extending the operational capability of the military observer. Figure F-2 shows the angular resolution capability of typical (10 to 20 power) optical devices. An angular resolution of 1 milliradian is equivalent to a resolution of 1 meter on a target 1 kilometer distant, or of 2 meters on a target 2 kilometers distant.

Figure F-2. Angular Resolution of Typical (10 to 20 Power) Optical Devices.



The dashed horizontal line indicates the expected resolution capability of the unaided eye under favorable viewing conditions such as high contrast targets and high illumination levels. The design limit of representative 10 to 20 power optical systems is indicated by the bar at the extreme left of the diagram ("Design Limit of Optics"). The next three vertical bars indicate the measured performance of such optical systems when the observer is static. The last three sets of vertical bars at the right of the diagram indicate the measured performance of existing optical systems when the observer is standing or riding in a moving vehicle. The upper set of bars represents the measured performance in the dynamic mode of observation without the use of image-stabilization optics. The lower set of bars indicates the measured performance achieved by the use of image-stabilization optics. The improvement is significant. The three sets of data are the results achieved with three different types of image-stabilization binoculars.

The resolution of an optical device given the illumination conditions and contrast is an indication of the level of detail in a target image presented to the observer. It is not necessarily an indication of the useful range of the device. As in the case of visual range of the unaided eye, the visual range of optical devices depends upon the illumination level on the target and background, on the acuity of the observer and related psychological factors, and on the transmittance of the atmosphere. The relationship among the angular resolution of a device, the range from the device to a target, and the linear resolution on the target is shown graphically in Figure F-3.

Figure F-4 represents the measured detection range of a camouflaged M60A1 tank in a simulated European scenario as viewed by unaided and binocular-aided vision. As can be seen from the test data, the use of binoculars has increased the range of 50 percent probability of detection from 750 meters to 1350 meters and has increased the probability of detection at 1000 meters from 24 to 75 percent.

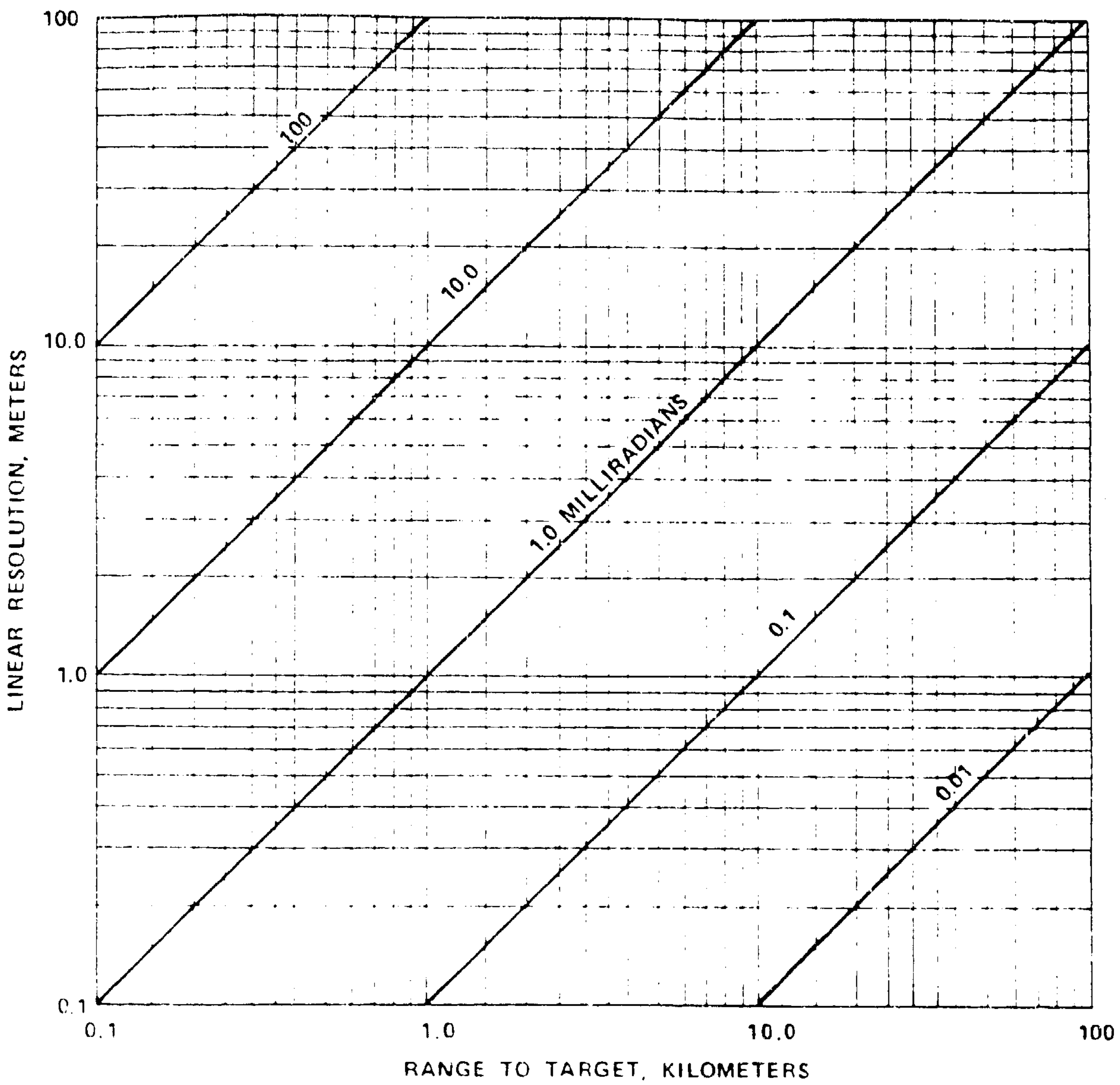
One of the earliest infrared imaging devices put into production was the hand-held metascope, which made use of a rare-earth phosphor to convert near-IR radiation (0.7 to 0.9 micron) to visible light. With suitable optics, a low-grade image of a nearby infrared-illuminated object could be formed. The metascope could also be used to detect radiation from infrared searchlights or vehicle night-driving lights. Metascopes currently employ an improved infrared-to-visible image converter tube and include a light source and infrared filter to permit map reading and other close-range activities.

Helmet-mounted infrared binoculars, using two image-converter tubes, are intended primarily as a night-driving aid. These binoculars receive reflected illumination from infrared-filtered vehicle headlights.

The Sniperscope consists of an image-converter tube, optics, and an infrared light source mounted on a rifle. The image-converter tube can also detect infrared sources passively within its field of view or make use of illumination from a remote cooperative source such as infrared zenon-plasma searchlight. Range is primarily dependent on the intensity of the light sources or the target infrared source.

The Sniperscope was superseded by the rifle-mounted Starlight scope. This is a direct viewing, passive imaging system using an image-intensifier tube sensitive in the visible and near-infrared as is the image converter. This equipment is effective at illumination levels as low as those from a moonless, starlit sky.

Figure F-3. Relationship of Angular Resolution, Range and Linear Resolution.



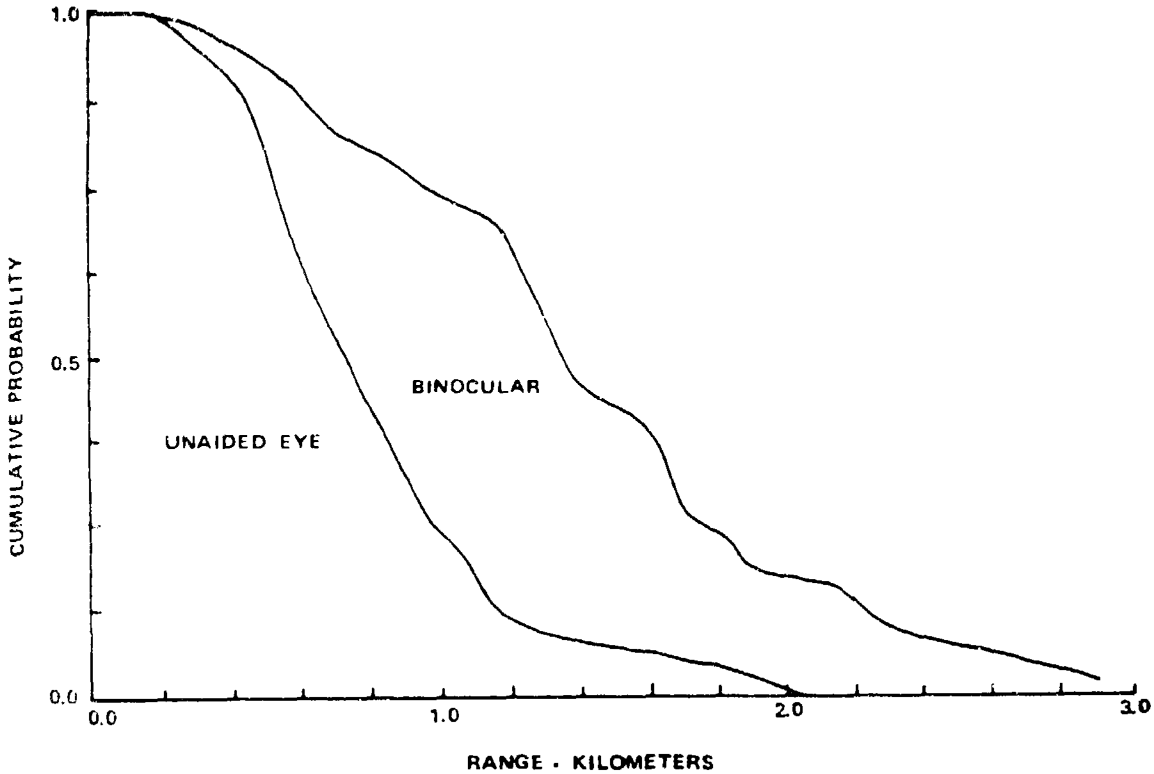


Figure F-4. Detection Range of Camouflaged M60A1 Tank.

Low-light-level image intensification devices are in widespread use by armor, infantry and artillery units throughout the world. This threat to camouflage is intensifying rapidly, especially near the FEBA.

Image intensified night vision devices have been produced in increasingly larger sizes for use on light machine guns, crew served weapons, tripods, tanks, and aircraft. Smaller units, such a night vision goggles, have been developed for use by aircraft personnel flying nap-of-the-earth configurations and by ground personnel for performing various nighttime functions. Range, nominally 300 to 3000 meters, is related to the level of illumination and to the diameter of the collecting optics of the device.

An image intensifier coupled to a conventional TV camera tube forms an assembly known as a LLLTV. This type of device permits remote viewing of intensified images on a television monitor with fidelity comparable to that of commercial television. Recent development in simplified LLLTV designs, change-coupled device (CCD) applications, microcircuits (MMIC) and power supplies have greatly increased the potential RSTA value of these systems. Very high resolution TV monitors are now available commercially.

While image intensifiers and LLLTV systems are essentially passive, sensing night-sky radiation reflected from the target, the range and target discrimination may be improved by integration with an active near-infrared illuminator. In a range gated configuration, a laser illuminator is pulsed and the LLLTV receiver is activated only for the period of time when the reflection is expected from the target. This approach illuminates the target without illuminating the background or backscattering radiation

from particles in the atmospheric path between target and receiver. Targets which blend into a distant background may show up as a silhouette if the range gate is set at the background distance. Again, camouflage is an obvious target.

Angular resolution varies with illumination level and is limited by screen quality. It is now on the order of 25 lines/millimeter permitting sensor resolutions of 0.1 milliradian or less. Due to coupling losses, the performance of LLLTV systems likely will never exceed that of the directly viewed image intensifier. Current availability of high resolution screens extends to 100 lines/millimeter.

It should be noted that effective range of these systems is dependent upon: target-to-background contrast, illumination, the diameter of the collecting optics (greater range for the larger systems), weather conditions (severe attenuation by fog and moderate attenuation by haze, rain, and snow), and the sensitivity of the image intensifier active surface to night-sky radiance.

F-3.3 Electro-Optical Systems.

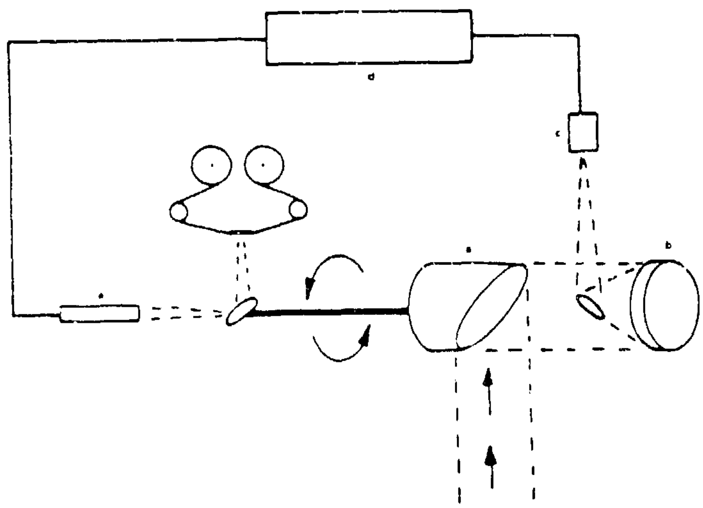
The preceding discussion of visual-assisted RSTA has already described electro-optical devices in the form of image intensifiers, LLLTV, and the night vision devices found with many small maneuver elements on the battlefield. There has been world wide interest in other electro-optical instruments in the form of active IR, thermal imaging and laser applications to obtain night fighting capabilities, to expand surveillance and target acquisition into the IR spectrum and to upgrade weapons terminal accuracy.

Passive IR sensors used in surveillance and target acquisition roles are image forming systems which sense the radiation emitted by objects within the field of view (FOV) of the system. This radiation usually is spectrally continuous over the entire electromagnetic spectrum, but is not constant in magnitude. The intensity of the radiation and the wavelength region over which maximum radiant energy or power occurs is a function of the absolute temperature and the emissivity of the object.

Most ground targets present a broad spectrum of IR radiation to thermal sensors. These targets include man-made objects such as roads, vehicles, structures, personnel and various equipment as well as such natural backgrounds as water, vegetation, earth, sand, snow and ice. Ground targets are opaque or nearly so and are reasonably close to ambient temperatures (i.e., 300°C). Some targets are distinguished by passive IR because they exhibit higher temperatures than their surroundings (ΔT). Typical targets are vehicles and their exhaust manifolds, power generation units and similar heat energy sources that appear as bright spots in the thermal IR spectrum.

At earth ambient temperatures of 300°K (27°C), peak radiant intensity occurs at a wavelength of about 10 microns. For warm and hot objects, the peak shifts progressively to shorter wavelengths. Only when the object is incandescent does a sufficiently large fraction of the total energy emitted occur at wavelengths short enough to be visible to the eye. Passive IR devices are designed to sense in the so-called "thermal IR" region (2.5 to 14 microns) where objects at temperatures from 200°K to over 1000°K radiate with sufficient intensity to be sensed by one or more of a family of IR detectors. The atmosphere is highly transparent at specific wavelength intervals over this span, with the "windows" at 3 to 5 and 8 to 14 microns of greatest interest for surveillance and target acquisition.

Optical-mechanical line-scanning techniques are widely used to record thermal imagery. Basically, IR detector elements are fixed in the instrument while FOV is passed before them systematically through the use of a rotating or oscillating mirror (Figure F-5). The detector thus scans the object plane. The detector output, varying with incremental differences in scene temperature and emissivity, is an electrical signal which can be displayed in real time, or can be recorded on tape or film for future examination. An IR image of the scene is formed from the detector signals by synchronizing the display scan with the optical-mechanical scanner.



THIS ILLUSTRATION SHOWS THE ESSENTIAL FEATURES OF SCANNING SYSTEMS. RADIATION STRIKES THE SURFACE OF A ROTATING MIRROR (a), AND IS REFLECTED TO THE SURFACE OF A PARABOLIC MIRROR (b), AND THEN TO A SOLID-STATE DETECTOR (c). THE OUTPUT OF THE DETECTOR IS AMPLIFIED (d), AND MODULATES THE OUTPUT OF A LIGHT SOURCE (e). THE MODULATED LIGHT IS RECORDED ON FILM (f).

Figure F-5. Typical Infrared Scanning System.

Characteristics of passive IR line scanners most significant to target acquisition and surveillance applications from ground, air and space platforms are:

(1) Total FOV or width of scan sweep in degrees.

(2) Incremental FOV or angular resolution in milliradians.

(3) Noise equivalent differential temperature (NEΔT); the effective temperature difference between adjacent resolution elements which produces a signal equal to the noise in the system. This is related to thermal resolution, which is the difference in temperature of two adjacent resolution elements of the same emissivity which can just be resolved in the imagery.

(4) V/H, the ratio of maximum aircraft speed to height above the ground, in radiants sec^{-1}, for which contiguous scan lines can be produced.

These four principal system parameters incorporate essential design features of a line scanner, including detector sensitivity in the spectral region of interest, detector response time or scanning rate, diameter of the entrance aperture and transmission of the optics, and electronic bandwidth and internal noise in the system. The display seldom places a limitation on detection but does limit recognition and identification. The four parameters are interdependent and, therefore, all cannot be optimized simultaneously in one system. Consequently, line scanners are designed to optimize those parameters which are of paramount interest for a given application at the sacrifice of less important parameters.

Range of line scanners can be determined from analytical expressions involving, at least indirectly, the parameters discussed. A range equation for detection by an IR sensor which calls out the essential consideration is:

$$R = (JT_a)^{1/2} \; A_o \; \frac{T_o}{f}^{1/2} \; (D^*)^{1/2} \left[\frac{1}{f^{1/2} \; (V_s/V_n)} \right]^{1/2}$$

where

R	=	range
J	=	radiant intensity of the target over the background $W(sr)^{-1}$
T_a	=	transmission of the atmosphere
A_o	=	area of the entrance optics
f	=	equivalent focal length of the optics
T_o	=	transmission of the optics
D^*	=	detectivity of the IR detector at the spectral range of interest
	=	instantaneous FOV of detector, or angular resolution
f	=	bandwidth of electronic system
V_s/V_n	=	signal to noise ratio of the system necessary for desired probability of deduction.

This expression shows that range is highly dependent on the thermal characteristics of the target, and on atmospheric conditions. D^* should be maximized, but theory indicates a limiting value dependent on wavelength of operation and the radiating properties of the background on which the target is superimposed. The instantaneous FOV is related to detector (or array) dimensions, as well as the optics; reduction of detector size has technical limits and the optical system has light diffraction limitations, both of which place a lower limit on angular resolution. High resolution combined with a large total FOV produces high information rates which is being exploited by advanced wide-bandwidth signal processing electronics. The large f tends to nullify range increases brought about by reducing the FOV. Scaling up the IR scanner system dimensionally increases range. Necessary design trade-offs are such that the weight of a given system design increases approximately as R^6.

The IR detector, the transducer of IR radiation to an electrical signal, continues to play a major role in the development of IR scanners to their present level of importance. IR detector development has gained impetus as a result of knowledge gained from recent technology advances in detector materials and array signal

processing. Improvements have been made in detector sensitivity, spectral extension to longer wavelengths in the IR, shorter detector response time, and fabrication of close-spaced linear and two dimensional arrays of very small detector elements.

Active IR sensors such as laser scanners discriminate among targets by their spatial and polarization characteristics in the reflected IR energy. Observed differences in specular and diffuse reflectance of target surfaces produce significant differences in the spatial distributions and polarization characteristics in the energy reflected from various target aspects.

Advancements in laser technology over the past two decades have led to broad applications of laser systems in tactical roles. These include target designators, range finders, multispectral scanners and doppler lidar (laser counterpart to radar).

Laser target designators (LTD's) are employed to guide bombs, missiles, and other projectiles to targets illuminated by the laser. The designator laser must be in the line-of-sight to the target and the laser beam must be reflected from the target with sufficient intensity and for a sufficient time to permit the homing device to acquire the target, lock on, and be guided to it. To the seeker, the target (by definition appears to be the source of radiation. It is desirable for the target of interest to act as a diffuser rather than specular reflector of laser radiation so that both the illumination and acquisition of the target are not dependent on direction so long as the laser source and the seeker are in the same hemisphere. In the wavelength from 1 to 4 microns, the reflectance of most targets is largely diffuse.

Important parameters of LTD/seeker systems which permit target acquisition and lock-on are the detector's sensitivity and the radiant power level at the seeker. It is important that lock-on occurs at sufficient range from the target to permit guidance-and-control to correct the flight path in order to hit the target. Range depends upon such factors as the characteristics of the laser source, the seeker, the target, and the prevailing weather conditions. Factors associated with the target include: (1) target reflectance coefficients, which specify the geometry and magnitude of diffuse scattering, (2) the effective target area relative to beam cross section area, and (3) laser-beam polarization.

A laser commonly used as a ground target designator in many armed forces around the world is the neodymium doped yttrium aluminum garnet (Nd:YAG), operating at a wavelength of 1.06 microns, a good atmospheric transmission window. The CO_2 gas laser, operating at a wavelength of 10.6 microns, can also be used as a designator. The TEA (transversely excited atmospheric pressure) CO_2 laser can be pulsed at rates exceeding 1000 pulses/second and has a higher energy output capability than the Nd:YAG laser. Reflected CO_2 beams from armored vehicles such as tanks, however, are predominately specular and this can affect the probability of the seeker acquiring the target. Ruby lasers operating at a visible wavelength of 0.694 microns, were used in a target-designator role in Southeast Asia but, because of the visibility of the beam, were found to be less effective than covert lasers operating in the IR spectrum.

The laser rangefinder finds wide application in ground combat situations primarily as an adjunct to conventional firepower. Such devices are especially useful when deployed on standard tactical systems such as tanks. Hand-held laser designators for target acquisition and fire control can be a distinct threat to camouflage.

The laser rangefinder comprises a pulsed laser and a collocated receiver. The rangefinder is able to determine distance electronically by comparing the time relationship of emitted pulses with received pulses. This is a line-of-sight system where the detectable radiation is reflected back along the incident beam path. As in the case of the laser designators, the target size, target reflectance characteristics, and atmospheric conditions will determine the reflected beam intensity at the rangefinder receiver. Lasers which can be used as rangefinders include ruby (0.694 microns), Nd:YAG (1.06 microns), and CO_2 (10.6 microns).

F-3.4 Battlefield Radars.

An effective all-weather surveillance and target acquisition system for tactical use commands high priority on the modern battlefield. Radar systems meet these RSTA requirements and have been developed and deployed world wide. Radar systems perform many important tactical functions including surveillance at fixed and moving targets, target acquisition and designation, weapons guidance, air defense, navigation, personnel detection, early warning and counter-mortar/counter-battery locations and tracking. Nearly every armed force possesses radar capabilities in some form, e.g. man-pack, truck-mounted, mobile and/or fixed installations and at least 20 countries produce and market radar systems world wide.

Micro wave sensors including radar, radiometers and various electronic intelligence sensors all represent some degree of threat to camouflage. The intelligence-gathering sensors can detect the presence of intentional or spurious missions from transmitters, ignition systems, electronic radiators or chemical combustion processes. They can also detect microwave radiation induced in potential targets by some outside stimulus. These sensors are also elements of the SIGINT activities, normally a part of battlefield RSTA operation.

Radiometric systems sense target temperature contrasts with the background. Metallic targets reflect the cold temperatures of the sky, while the surrounding land and vegetation appear warmer. Passive radiometers are in fact bistatic radar systems. Active radiometric systems are radars which transmit noise signals. The larger the target radar cross section, the more signal is reflected, and the hotter the target temperature appears. Targets must have a reflectivity differenc from that of the background for the radiometer to see the contrast. Methods of controlling the radar cross section will thus control radiometric reflections, either active or passive.

Radar systems have experienced extensive development as primary surveillance, navigation and guidance sensors since World War 11. A radar system comprises a transmitting system which generates a propagating electro-magnetic signal and a receiving system which analyzes the signal reflected off the target. There are many types of radar systems. They may be mono-static (receiving and transmitting systems collocated), bistatic or polystatic (several separated receiving systems for one transmitting system). They vary from short range radar fuzes with a range of a few centimeters to very large range radar astronomy systems receiving signals reflected from other planets. They vary in complexity from simple intrusion detectors to highly sophisticated phased-array systems receiving signals from any rapidly moving, similar targets and discriminating among them. It is necessary to examine the entire field of radar systems in order to project the future system developments of interest to Army camouflage planning and decision-making. Every type of Military radar including man-

pack, transportable, battlefield surveillance, mortar locating, aircraft and missile detection and tracking radar, fuzes, missile guidance, terminal homing, reconnaissance, and surveillance may interact at some point with camouflage systems.

The important parameters of military radar systems are their frequency, range and resolution. Table F-2 is a listing of the principal bands. Table F-3 shows characteristics and attributes of the radar frequency bands.

Table F-2 Radar Band Designations

Band	Frequency, MHz	Wavelength, Cm
A	0 - 250	120 -
B	250 - 500	60 - 120
C	500 - 1,000	30 - 60
D	1,000 - 2,000	15 - 30
E	2,000 - 3,000	10 - 15
F	3,000 - 4,000	7.5 - 10
G	4,000 - 6,000	5.0 - 7.5
H	6,000 - 8,000	3.75 - 5.0
I	8,000 - 10,000	3.0 - 3.75
J	10,000 - 20,000	1.5 - 3.0
K	20,000 - 40,000	0.75 - 1.5
L	40,000 - 60,000	0.5 - 0.75
M	60,000 - 100,000	0.3 - 0.5
FORMER BAND DESIGNATIONS		
P	300 - 1,000	30 - 100
L	1,000 - 2,000	15 - 30
S	2,000 - 4,000	7.5 - 15
C	4,000 - 8,000	3.75 - 7.5
X	8,000 - 12,500	2.4 - 3.75
Ku	12,500 - 18,000	1.67 - 2.4
K	18,000 - 26,500	1.0 - 1.67
Ka	26,500 - 40,000	0.75 - 1.0

Table F-3. Radar Frequency Band Characteristics and Attributes.

FREQUENCY BAND DESIGNATION	FREQUENCY MHz	WAVELENGTH Cm	CHARACTERISTIC ATTRIBUTES
L	1,000 - 2,000	15 - 30	Popular for aircraft surveillance radars Relatively hi-power, large antenna aperture Good MTI, angle resolution Low external noise
S	2,000 - 4,000	7.5 - 15	Good angle resolution, reasonable size antenna Low external noise MTI not as good as L-band Weather can degrade A compromise frequency for medium range aircraft detection/tracking
C	4,000 - 8,000	3.75 - 7.5	Compromise between S and X bands Moderate range surveillance with precision at long range for accurate missile tracking Long range weapon control radars
X	8,000 - 12,500	2.4 - 3.75	Popular frequency for military weapon control Airborne weather-avoidance Doppler navigation radars Convenient size, mobile, light-weight Short range info-gathering, surveillance Narrow 1 beam widths, antennas 6' width Small enough for man-pack Good resolution in both angle and range
Ku	12,500 - 18,000	1.67 - 2.4	Water vapor resonance at 22.2 GHz
K	18,000 - 26,500	1.0 - 1.67	High power difficult to achieve
Ka	26,500 - 40,000	0.75 - 1.0	Antennas are small, receivers are less sensitive Higher external noise Increased atmospheric attenuation Windows at 15GHz, 35GHz

Table F-3. Radar Frequency Band Characteristics and Attributes. (Continued)

FREQUENCY BAND DESIGNATION	FREQUENCY MHz	WAVELENGTH Cm	CHARACTERISTIC ATTRIBUTES
MMW	40,000 - 60,000 60,000 - 100,000	0.5 - 0.75 0.3 - 0.5	Wide Band widths, avoids other EN interference Narrow antenna beams, relatively small aperture Same limitations as K-band Weather clutter, atmospheric attenuation increase Windows at 94 GHz, 140 GHz Wide band widths, narrow beam widths desired to to classify target types
LASER			Reasonable coherent power and efficiency Narrow directive beam widths at IR, visual UV regions Good range resolution and angular resolution Good for information gathering - range, imaging Less suited for surveillance, small aperture and narrow beam Unable to operate effectively in rain, clouds, fog

Radar range is a design parameter and can be set at any distance, but against ground targets, microwave radar is basically limited by the line of sight. The line of sight depends upon the height of the radar antenna and the height of the target. Extending the range can be accomplished by: (1) elevating the radar (2) use of over-the-horizon radar operating in the high frequency (HF) bands, or (3) by taking advantage, when possible, of non-normal propagation conditions such as ducting.

In radar, two types of resolution are important: range and azimuth. Range resolution is largely determined by the pulse length chosen. Range resolution and range accuracy of battlefield surveillance radar, particularly those using pulse compression techniques, are quite high and appear to be sufficient for many applications.

High angular resolution is a desirable property for radar systems. The angular resolution of early radars was limited by the physical size of the antenna. There is a definite relationship between the size of an antenna measured in wavelengths and its directivity. Since at that time an increase in directivity was the way to obtain an increase in angular resolution, the optimal ways to improve resolution were to use larger antennas or to operate at shorter wavelengths. This situation applied particularly man-packed radars since there was a limit to the physical size of the antenna that can be man-packed, and since frequencies higher than J/K-band were severely affected by weather conditions. The angular resolution of man-pack radars tended to remain fixed at about 10 milliradians for older systems.

Several signal-processing techniques have been devised to increase radar performance. One is termed "monopulse" and involves the use of two separate antenna feeds and the sums and differences of the signals from these feeds. By proper manipulation of the signals and antenna positions, a null is pointed toward the target on the difference channel. This null can have one-tenth the beamwidth of the original antenna pattern and thus increase the directivity. This technique is primarily implemented against targets where the background does not produce much clutter ... .

... technique is the synthetic aperture principle. The physical antenna aperture is moved and the signal added coherently over a period of time. This technique has improved the resolution of airborne radars by as much as two orders of magnitude. Against moving targets, a cross-over time can be computed which indicates the maximum time that a signal may be integrated without the motion of the target degrading the integration. The resolution of synthetic aperture radars (SAR's) is primarily limited by the memories of the associated computer systems. Angular resolution (meters per kilometer range) for representative synthetic aperture radars have exceeded 0.05 m/km.

Since World War 11, much effort has gone into the features of radars which might be explored for cueing man-made targets. Extensive efforts have gone into polarization and cross-polarization studies, target fluctuation studies, and target anguli sensitivities. Even more work has gone into moving target indicators (MTI's) and Doppler modes of detecting both high-value targets and individual soldiers on the basis of their motion.

One parametric form of the radar range equation is:

$$R^4 = P\ A^2\ \sigma/(4\pi\ \ ^2S)$$

where R is the range at which the receiver power is equal to the receiver minimum detectable signal S. A is the antenna effective aperture area, P is the transmitted power, is the wavelength of the radar energy, and σ is the radar cross section of the target. This equation is useful for rough computation of range performance, but is simplified and gives overly optimistic values.

When the target is located in a background which reflects radar energy, these unwanted clutter echoes can severely limit the deductibility of the target. When clutter power dominates receiver noise power, the range equation reduces to an expression for signal-to-clutter ratio.

$$R = 2\sigma/\{\sigma^{o}\theta c\tau\ \sec(\phi)\}\ (S/C),$$

where R is the range to a clutter patch, σ^{o} is the normalized clutter coefficient, Θ is the azimuth beamwidth, c is the velocity of propagation, τ is the pulse width, ϕ is the grazing angle, and (S/C) is the signal-to-clutter ratio of the receiver. The detection range is thus seen to be dependent on the ratio of the target cross section to the clutter cross section of the background - and not just on the target cross section alone.

A number of microwave systems have been developed which take advantage of the fact that metallic targets resonate at frequencies different from those of an exciting energy source, and thereby enable positive identification of metal targets. These systems are of interest to camouflage because of their possible potential for close-in target detection, either by themselves of in conjunction with more conventional radar.

One called METal Re-Radiation RAdar (METRRA) was capable of sensing and detecting stationary and quiescent metal targets through foliage at frequencies of around 220 to 450 MHz and then detecting any resulting third harmonic energy or other frequencies created by the non-linear electrical contacts inherent in man-assembled equipment, but not present in nature. The METRRA systems exhibited minimal detection ranges (approximately 1 kilometer for 100 kilowatts) and a very low resolutions but demonstrated a capability of detecting targets in natural clutter by statistical comparison techniques.

The battlefield radar threat includes man-portable radar with effective range to 5-10 km, vehicle-mounted radar covering ground targets to 10-20 km and complex trailer-mounted semi-mobile surveillance with ranges out to 20-50km depending on terrain and site limitations.

The small (10-50 lbs.), low power (10 mW - 1 kW) short range radar systems include man-pack surveillance radar for worldwide use some of which are similar to the US AN/PPS series of lightweight ground sensors. These devices operate generally in the I/J bands and demonstrate personnel detection to 1 km and 5 - 10 km target requisition against vehicles in clutter, moving or stationary. Sector scan and MTI operation can provide accuracies of ± 20m range and ± 10 miles azimuth. These items may be deployed as remotely controlled or automatic sensors, individual or netted and may be interlinked with other cueing sensors such as acoustic, radio-DF or emitter detectors.

The somewhat larger (50-2,000 lb), higher power (1 - 10+ kW) vehicle-mounted surveillance radars, some operating in the K-band for detection/tracking of ground targets and artillery fire adjustment, have detection ranges out to 30+ km and improved azimuth accuracy (± 1 mil) and range resolution (± 10 m) with higher performance (2-4 K pps), narrow beam width (.1°-1°) and short pulse width (<1 μs).

Surveillance radars of this type are known to operate with other sensors such as laser designators, sound/flash detection and low-lighted TV to take advantage of multi-sensor target detection/identification capabilities.

The ground surveillance radar threat extends to larger, highly mobile, self-contained, trailer-mounted units operating in the I/J bands with peak powers up 100kw and weapon location/target location coverage to 50 km. Typical configurations include electronically scanned phased array antennas with computer controlled digital data processing, pencil-beam azimuth sector scan, multiple target handling and improved clutter/ECM performance. Radars of this type with accuracies on the order of 1/2 mile and 1 meter range are generally available worldwide.

F-3.5 SIGINT

Signal intelligence detects, locates and analyzes signals of all types from enemy radios, radars, on-board electronics navigation, GCI, command posts and command centers. Particular interest is focussed on targets where camouflage is likely to be employed (e.g. major ground force command centers, nuclear weapon supply depots, airfields, air defense and major military installations such as depots, transportation, and parts storage locations). In most armed forces SIGINT is generally not considered independently reliable and other RSTA means are used to corroborate SIGINT data. However, for well organized/equipped forces (e.g. USSR) SIGINT provides up to 80% of military intelligence information and thus is an important factor in maneuver success. Corroboration requires a close and continuous integration of all RSTA assets with target priorities, reconnaissance forces and counter measure forces acting in common.

SIGINT intercepts cover all types of signals including test (clean/enciphered), Morse code, radioteletype, radio relay, tropiscatter communication etc. Some signal sensors can serve as target cues for recce of camouflaged targets, e.g., sound/flash ranging, artillery/counter mortar, radio intercept/DF and battlefield surveillance radars. The high degree of interaction with other RSTA resources including airborne elements assures fast (man real-time) data-processing and discrimination of SIGINT in the RSTA system. The threat to camouflage is very sensitive to the SIGINT attributes and characteristics.

F-3.6 Integrated RSTA.

Integration of RSTA systems in battlefield applications is happening now to a limited extent. Future integration involving secure communications and control, IFF, C^3I networks and fusion of target information from all sources is expected to expand RSTA capabilities exponentially. Integration of RSTA functions means that camouflage must consider combined, simultaneous sensor looks at targets that consist of multisensor, multispectral, and complex signature analysis, at any time.

Secure communications will provide dependable command and control. High confidence in data/information transfer is maintained through elimination of false signals and avoidance of disruption in transmitting/receiving RSTA information. The expected increase in numbers and sophistication of RSTA systems will no longer restrict operations to internal or very short comm links. Increased complexity of advanced sensor systems will make use of agile array scanners, spread-spectrum coding, frequency hopping, adaptive antenna patterns, sidelobe suppression, bandwidth limiters, adaptive sidelobe suppression, adaptive filters and transmitters with high peak power and low duty cycle. Overt/covert communications with frequency agile, timed, pulsed signals will serve sensor data exchange and computer processing involving remote, distributed sensors and command centers. Real time processing and transfer is likely.

IFF systems developments for integrated RSTA are expected to produce discrimination techniques, unique secure passwords, parallel processing and adaptive logic options for RSTA operations in EW environments. Advanced signal acquisition and sorting with signal modulation and power requirements for IFF are expected to involve new developments in mass storage devices (dye-polymers, photorefractive crystals, etc), parallel processing (3D chips, transputers, neural networks, etc) and sensor fusion for advanced discrimination and pattern recognition.

Integration of sensor information from diverse tactical, instrumented and human sources in real or near-real time is fundamental in RSTA fusion technology development and system design. Data acquired from various instruments, air/ground sensors and situation/simulation mosaics must be processed and correlated to produce a single coherent output or pattern useful for target validation and fire decisions.

Fusion processes contemplate extensive use of situational input data, knowledge bases, CCM techniques, SIGINT, imagery and correlated target information to provide timely unambiguous target detection and classification. The simplest examples of fusion are those that process, correlate, and communicate such target data and corollary information for co-located or multi-sensor equipment where coordinate systems, viewing angles and target aspect are established *a priori*.

Fusion for RSTA systems applications involves hardware and software structures for acquiring and processing target information in a collaborative system that can:

- Interpret acoustic, magnetic, radar, IR and optical intelligence
- Conduct the necessary communications filtering, multiplexing, switching and interface translation
- Conduct spread-spectrum, CCM and packet switching.

At the module level these functions may incorporate intelligence input data processing, work station operations, integration with forward sensors and many C^3I communications and network functions.

System requirements for fusion are being developed in the RSTA technology base to guide the design applications of these complex processes and their modular realizations. Especially useful for RSTA as well as C^3I are networks designed to access data bases that are distributed among various nodes in this system.

Real time integration of RSTA on the battlefield will challenge camouflage to diversify techniques and to actively pursue dynamic responses to these threats to security and survivability of friendly forces.

F-4 AIRBORNE THREAT

The airborne threat to camouflage encompasses nearly the entire spectrum of RSTA sensors: visual observers, radio DF, side-looking radar (SLAR), synthetic aperture radar (SAR), millimeter wave radar (MMW), low-light-level TV (LLLTV), forward-looking IR (FLIR), and photographic intelligence (PHOTINT). Signal intelligence (SIGNT) and communications intelligence (COMINT) are not considered here).

F-4.1 Visual Reconnaissance.

The visual observer's interaction with camouflaged targets on the battlefield is, even today, the predominant detect/recognize/identify event of target discovery and classification.

The visual signature of an object and its background is that collection of target features, characteristics, and attributes which, in the surround and environment presented by the tactical scene, enables a human observer or sensor system, or some combintion of both, to detect and/or recognize and/or identily that particular object and thus discrininate it from the background. In fact, this definition generally applies to target signatures of all kinds where direct vision may be aided by photographic, IR, or microwave devices. The final step in the process of reading out or interpreting the target scene is, with the exception of moving targets (doppler MTI) and acoustic signatures, a visual process.

Visual signatures contain the characteristics and attributes of the target object and the background within the field-of-view (FOV):

- Size/shape/shadow (includes edges, lines, contours, and aspects).
- Color/hue/texture.
- Movement/target history.
- Temperature.
- Reflectance/luminance (includes "specular" glints and highilghts).
- Inherent/apparent contrasts (includes detail contrasts).
- Spatial frequencies (includes "gray" shades, background complexity, unique patterns).
- Cues (includes effluents, dust, tracks, firing, deployment geometry.

Conditions directly affecting the visual signatures aside from sensor/instrument performance and certain other modulation peculiar to particular wavebands include:

- Irradiance/brightness/illunination (includes position of the sun and other irradiance sources).
- Terrain and line of sight.
- Visual path atmospherics (includes visability, scattering, turbulence/ refraction, absorption, humidity/water content, wind, precipitation).

These are the factors and parameters that must be measured to provide quantitative definition for target signatures including visual observations. Each of the targets listed in the Camouflage Critical/Camouflage Sensitive represent a priority set of the tactial target objects of interest for visual camouflage development. To illustrate the visual acuity and visual range performance of qualified airborne observers against typical tactical targets, the aggragated results of 34 qualified helicopter pilots with combat experience is shown in Table F-4. The helicopters were flown at 150 feet above the terrain over representative test grounds on a clear sunny day (average luminance and contrasts).

Table F-4. Target Acquisition Range as a Function of Target.

Target No.	Target type	Av. acquisition range, m*
1	M48 Tank	1,062
2	Howitzer	674
3	Truck convoy	1,000
4	Radar van	1,155
7	Bridge	478
9	Radar van	555
10	Radar van	504
11	Guns	297
12	Searchlights	359
15	Tank	347
16	Radar van	420
17	Amphibians	686
19	Trucks	561
22	Supply dump	509
24	Bridge	841

* Note: Acquisitive range valid to 1 significant figure

No special cover or concealment was involved in this test. If camouflage screens or nets were introduced, many of these targets would be undetected on first pass and most might remain unidentified for the duration of the mission.

Manned aircraft and helicopters with human observers are a common element in the camouflage threat from almost every potential opponent. Likewise image intensification devices such as LLLTV in day-night sights some over stabilized platforms provide high resolution target imaging combined with EO imaging/range finding/target designation. Head-up displays (HUDs), though not primarily intensification devices can integrate many other target cues that may compromise the camouflage treatments, particularly IR or radar surveillance/tracking devices. Image intensifiers output may be combined with computer-generated information (e.g. target profiles, pattern recognition aids, cueing sensor inputs) to give the visual observer significant advantage in relating scene presentations to target presentations so that the camouflaged targets are inferred on imputed rather than actually detected.

F-4.2 <u>Airborne</u> <u>Radar</u>.

Aerial RSTA is comprised of radar sensor systems as well as visual, photo, IR, SIGINT and TV systems. Major advantages of air platforms are the increased detection ranges and broad sector coverage of the battlefield. In addition, real-time comlinks can be used to transmit information and target data to all other tactical units.

The use of aircraft platforms to support tactical ground forces is becoming more common. The on-board sensor systems include radar, visual imaging, IR scanners, photographic and a variety of electronic warfare systems, some of which may work in conjunction with RSTA such as SIGINT. Advanced TV systems with high resolution and real-time downlink communications have the ability to identify many tactical targets and is a definite threat to camouflage.

Day-night IR line-scan systems in combination with radar imaging and accurate navigation capability are increasingly effective in locating tactical targets. Fusion of target intelligence and the addition of MMW to the integrated RSTA systems will present a formidable threat to current camouflage capabilities.

A key sensor system for airborne RSTA is the Side-Looking Airborne Radar (SLAR). These systems transmit/receive their own energy to form a radar image of terrain in a strip to the left and right of the aircraft platform flight path. Because of the forward motion of the aircraft, such strips can be displayed on a scope or recorded on film to produce a complete terrain image. SLAR field of view may cover a wide swath (e.g., 30-40 km) rapidly from appropriate high altitudes with little scale distortion. Day-night and all-weather high quality imaging can be generated from long stand-off ranges.

Image processing of SLAR data may be entirely optical, utilizing EO or acousto-optic technology. Such systems have been highly developed and optical signal processing is a worldwide capability. More recently, the revolutionary advances in computer-based digital computer capabilities, the opportunity to exploit real-time signal and image processing (e.g., parallel processing, micro-electronics, data storage) and image enhancement techniques. In this area as well as electro-optical IR, many signal processing applications depend on spectral analysis and the decomposition of signals into frequency components. Different methods (e.g., FFT or Walsh-type transform) may be utilized but the advantage lies in being able to process extremely large amounts of data and conduct millions of arithmetic operations per second. If such capabilities are combined with high speed data links for communication with tactical units and commonds as well as other elements of integrated RSTA systems, the power of computer-based signal processing can be realized in terms of target detection/identification/location and prompt tactical action to kill/neutralize all such targets. As RSTA target information increases, so does the difficulty of concealing or disguising the target with various camouflage techniques.

Application of advanced signal processing to synthetic-aperture-radar (SAR) offers a real-time RSTA capability with even finer resolution than other radar technologies. The SAR technique was only one (or at most a few) radiating elements on an aircraft. As the radiating element translates in space with the aircraft, radar signals are transmitted and received and placed in storage. Both amplitude and pahse of the received signals are preserved. After the aircraft has traveled some distance, the signals in storage look like signals that would have been received by elements of a linear array. Processing these signals in the same manner as those of a linear array has the effect of simulating a long, effective antenna aperture, hence the term "synthetic aperture." The unique SAR characteristic is that azimuth resolution is independent of the range. Signal-to-noise is proportional to the size of the range-resolution element and is inversely proportional to the third power of the range. Good resolution is obtained by transmitting short pulses or by frequency-modulating the transmitted signal and using pulse-compression techniques. Reliable detection results

when the area of the radar resolution cell at the ground target is small and hence the background clutter is proportionally limited. SAR imagery is known for exhibiting fine detail. Moving target indicator (MTI) techniques may also be used to utilize doppler effects of moving targets to improve signal-to-clutter ratio with spatial filtering that suppresses fixed targets and enhances moving target detection.

F-4.3 Airborne IR.

IR systems for airborne RSTA may be divided into several types depending on application and type of scan. Down-looking IR line-scan systems were developed to record information on film for subsequent analysis. These systems operate like panoramic cameras with the scan across the flight path as one axis of scan and the motion of the aircraft as the other axis. Forward-looking IR (FLIR) systems, including thermal imaging systems, scan a raster pattern similar to TV. FLIR information for RSTA is usually displayed in real time.

A typical FLIR system that might be used for reconnaissance as well as weapon control could be configured as follows:

Field of View (FOV) - wide	10° X 10°
- narrow	2.5° X 2.5°
Instantaneous resolution (mrad)	1.0/0.2
Optical aperture (mm) - wide FOV	1.0
- narrow FOV	0.2
Optical transmission (%)	≈ 50
CRT display - no. lines	200
- frame rate (Hz)	25
Detector array (≈ 100 elements) (thermo electrical cooling) (≈ 100 elements)	For 3-5 μm HgCdTe or PbSe
(≈ 100 elements) (Joule-Thompson cooling)	For 8-14 μm HgCdTe
Tank recognition range (km)	4 approximately

Ground targets present a broad spectrum of IR radiation to IR sensors and include man-made objects such as roads, vehicles, structures, personnel and various equipment as well as such natural backgrounds as water, vegetation, earth, sand, snow and ice. Ground targets generally are reasonably close to ambient temperatures (i.e., 300°C) but some are distinguished by passive IR by exhibiting higher temperatures than their surroundings (T). Typically, these targets are vehicles, their exhaust manifolds, power generation units, or similar heat energy sources that appear as bright spots in the thermal IR spectrum.

Peak radiant intensity at earth ambient temperatures (e.g., 300°K or 27°C) occurs at wavelengths around 10 microns. Warm or hot targets shift the peak toward shorter wavelengths. IR detectors such as PbS, GdAs, or HgCdTe are capable of sensing objects in the thermal IR waveband (2.5 - 14 microns) where object temperatures of 200°K - 1000°K+ cause sufficient radiation intensity to be seen by one or more of a family of detectors. For RSTA, the atmospheric windows at 3-5 microns and 8-14 microns receive most attention.

As described previously under the ground threat for IR line-scanners, an IR image of the scene is formed from the detector signals by synchronizing the display scan with the optical-mechanical scanner. The characteristic of airborne passive IR line-scanners that are significant for RSTA include:

- FOV or scan width in degrees.
- Angular resolution in mrad.
- Noise equivalent differential temperature (NE T).
- Ratio of aircraft speed to height above ground (V/H) in radians/second for contiguous scan lines.

In addition, the range equation for IR sensor target detection is highly dependent on the thermal character of the target (which camouflage can determine), atmospheric conditions, the detectivity, D*, of the detector material and the design parameters of the electro-optical system.

Since the IR detector is the transducer of IR target scene radiation into electrical signals, detector development is a focal point for future airborne line scanners. Instantaneous FOV is related to detector (or array) dimensions as well as the optics. Reduction of detector size has technical limits and the optical system has light diffraction limitations, both of which place a lower limit on angular resolution. High resolution combined with a large total FOV produces high information rates which is being exploited by advanced wide-bandwidth signal processing techniques. The large bandwidth tends to nullify range increases brought about by reducing the FOV. Scaling up the IR scanner system dimensionally increases range. Necessary design trade-offs are such that the weight of a given system design increases approximately as R^6.

Large IR focal plane arrays with alternative scanning or storing interrogation methods and digital signal processing advances are providing significant performance up-grades for airborne systems. Developments in photoconductive as well as photovoltaic detectors and advanced applicaitons of change-coupled devices are contributing to greater target discrimination capabilities and IR search-track design improvements for RSTA.

Expanding applications of fiber optics and micro electronics in aerospace systems offers substantial increases in data handling, wavelength division multiplexing and integration of multisensor multiband and multifunction systems as airborne platforms. Reliability and performance trade-offs indicate continuing evolution of systems integration of passive IR, image intensifiers (II) and active laser IR ultimately leading to reliable sensor fusion and combined operations. For camouflage, joint operations of sensor RSTA suites multiplexes the single target responses required to meet signature suppression and detection avoidance in a timely manner.

Multispectral line-scan laser systems concurrently utilizing various types of lasers such as argon, krypton, Nd:YAG, CO_2, and possible free electron lasers (timeable) operating in the visible and IR spectrums have been used to illuminate on-the-ground objects, thereby providing a composite image composed of variations of the spectral reflectances of such objects relative to the background. The laser beams scan the FOV in raster fashion with optional modes of digital signal processing that may include ground/airborne computer systems and/or ground-based computer analyses of satellite signal transmissions. Advanced signal processing can be systematically employed to identify complex ground target signatures. The narrow laser beam width and the speed of the scan make it almost completely undetectable, either by eye (for argon and krypton lasers) or by IR warning receivers (for Nd:YAG and CO_2 lasers).

Lasers are feasible for simultaneous pulsed target cueing within the scene displayed by a FLIR thermal imaging system. The wavelength of the CO_2 laser, 10.6 microns, is compatible with the spectral band, 8-14 microns, employed by FLIR systems. In the case of man-made targets usually of interest, reflectance tends to be predominantly specular at 10.6 microns as compared to natural backgrounds. Therefore, man-made targets are highlighted by the laser beam and direct the viewer's attention to that part of the scene where the highlight occurs. The CO_2 laser also has shown promise as a general scene illuminator for the FLIR for inspection of all details.

The range and image quality of multispectral laser scanners depend on reflectance differences between targets and naturally occurring objects. The reflection contrasts can change during the day with atmospheric conditions (rain, snow, dust, etc.), target activity (warm surface melting the snow or ice, for example), and with seasonal and scenario changes.

Combined navigation/targeting IR systems are in use that may optionally employ FOV-targeting FLIR's and/or laser designators/rangefinders with advanced computer data processing for day/night target acquisition and precision weapon delivery. This insures maximum stand-off, first-attack success for guided/unguided weapon delivery of laser guided rounds. Recent versions of these systems now becoming available world wide are compact, light weight, modularized and computer controlled and utilize multi-band IR to challenge camouflage of battlefield targets.

A continuing problem for all imaging IR sensors is the capability to define targets rapidly enough in a clutter background. Spatial characteristics of imaged targets when contrast and resolution are sufficient can provide the principal target signature quality for most observers. Spatial characteristics with hot spots are generally interpretable even in the presence of clutter and zero T. Fine structure signature analysis of spectral returns from cluttered targets can make use of advanced FLIR raster scan techniques, microcomputers and parallel processing to achieve high resolution surveillance and target acquisition.

F-4.4 Photographic Systems.

Photographic reconnaissance constitutes a primary source for tactical information on ground targets. The primary reconnaissance mode is aerial photography utilizing cameras (and IR systems) to record ground-target images on film. Modern military photographic systems are mounted on a variety of aerial platforms. Remotely piloted vehicles and battlefield surveillance aircraft take photographs from heights of 100

meters and greater above ground level. High performance reconnaissance aircraft can take photographs from heights in excess of 20 kilometers. Satellite photography occurs at heights of 160 kilometers or more. Photography at any height is subject to the restrictions of adverse weather, cloud cover, and insufficient nighttime illumination.

Relatively sophisticated cameras with large film formats, automatic exposure cycles, and interchangeable lenses used in vertical and oblique modes continues. Improvements in resolution have been realized through the development of a number of reconnaissance and cartographic cameras over the last 20 years. Significant improvement in the inherent resolution of the aerial photographic camera resulted from the development of image motion compensation devices and stabilizing platforms.

Resolution of the photographic image at the target is related to the height of the camera above ground level, the focal length of the lens, and the achievable resolution of the film if the limiting effects of the atmosphere are ignored.

$$T = \frac{H}{25.4\ FL}$$

T = target resolution, feet
F = lens focal length, inch
L = film resolution, lines/mm
H = target height, feet

For example, a photograph taken at 25,000 feet above ground level through a 10-inch focal length lens onto film with a resolution of 100 lines per millimeter will have a resolution on the target of about one foot.

The resolution at the target is directly proportional to the camera height. This means that low level photographs contain more detail than photographs taken at a greater height with the same camera.

Resolution varies across the photograph, and is best at the point directly below the camera. As in the situation shown in Figure F-6, the resolution at the edge of a panoramic photograph (where the slant range is twice the height) is four times as large as the minimum target resolution distance.

For example, a camera-film-processor system with an achievable angular resolution of 0.03 milliradians is flown 20 kilometers above a target. The minimum resolution is 0.6 meters. Near the edge of a vertical photograph where the range is 40 kilometers, the target resolution is 2.4 meters.

The ground coverage of a single aerial photograph depends upon: the field of view of the lens, the number of lenses in the camera, the orientation of the lens axis with respect to the vertical, and the height of the camera above ground. The field of view, in turn, depends upon the focal length of the lens and the film format. Figure F-7 shows three typical patterns.

$$T = \alpha R^2/H \qquad\qquad T = \text{Target resolution}$$

$$T_{min} = aH$$

T = Target resolution
α = Camera angular resolution
H = Camera height
R = Slant Range

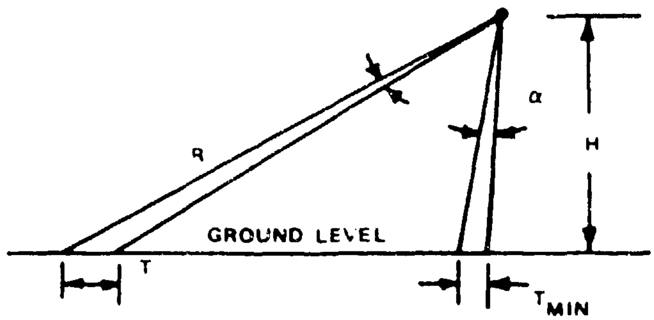


Figure F-6. Slant Range Resolution.

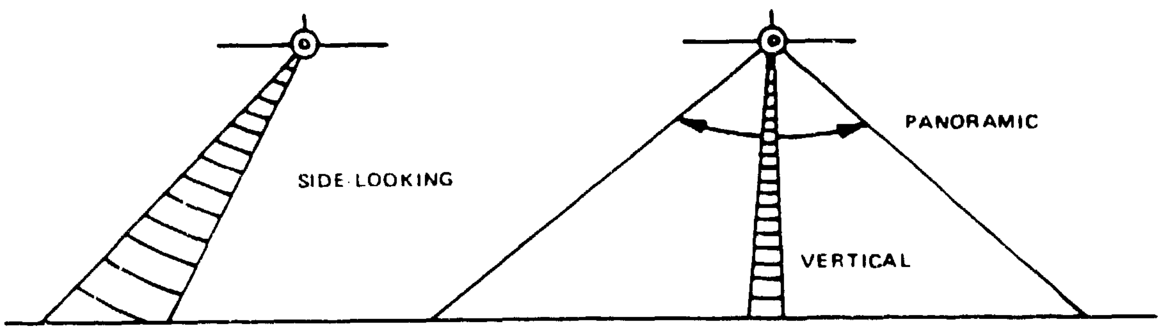


Figure F-7. Aerial Photography Ground Coverage Patterns

There are five principal types of aerial photography:

- Black and white in the ultraviolet region (0.35 to 0.38 microns)
- Black and white in the visible region (0.38 to 0.70 microns)
- Black and white in the near-infrared region (0.70 to 0.95 microns)
- Color in the visible region only (0.38 to 0.70 microns)
- Infrared color (camouflage detection) in the visible and near-infrared region (0.60 to 0.90 microns) Data on specific film-filter-camera combination are available in relevant reference manuals. Ultraviolet photography and camouflage detection photography are of particular interest to this Guide and are explained in the following two paragraphs.

Ultraviolet photographs are a record of the reflectance of materials in the near ultraviolet region. Snow has a high reflectance in both the near-ultraviolet and in the visible region. While many white coatings have a high reflectance in the visual region and a low reflectance in the near-ultraviolet region. Such artificial coatings blend with a snow background in black and white and in color photographs, but may appear as black objects against a white background in ultraviolet photographs.

Camouflage detection photographs are a record of the reflectance of materials in the 0.60 - to 0.90 - micron region. In this region, living foliage changes from a low reflectance in the visible portion to a high reflectance in the near-infrared portion, whereas many green coatings exhibit a low reflectance in both portions. Camouflage detection film exploits this difference and records live foliage as magenta (bluish red) and low infrared reflectance material as other colors. These other colors, in an otherwise magenta image, provide strong detection cues to artificial, man-made objects.

Unlike conventional color film which has three layers sensitized to blue, green, and red, camouflage detection film has three layers sensitized to green, red, and infrared, A #12 yellow filter (minus-blue) is used to eliminate the blue radiation which would affect all three layers. The green-sensitive layer produces a yellow positive image, the red-sensitive layer produces a cyan (blue green) positive image. Foliage records as red or magenta on this film because it is highly reflecting in the infrared region which produces a thin cyan image. This then allows red from the other two layers to show through strongly.

Multispectral photography is a generalization of the above ideas to more than one or two spectral bands. If a target is spatially indistinguishable from the background in one spectral region, it may contrast with the back-ground in another region of the spectrum and thus be spectrally detectable. Cameras for multispectral photography consist of multiple lens-filter-film combination or a camera with one lens and multiple prism-filter-film combinations. Widespread use of multispectral surveillance will require that camouflage materials match the spectral reflectance of the background throughout a large region of the spectrum, not just in isolated bands within that region.

Photographic processes can be further manipulated to secure more information. The use of color photography is well known as a means of adding additional identifying cues to objects in the photograph. This is achieved through a sacrifice in sensitivity, contrast and detailed resolution. What is not immediately apparent is that all color photography is artificial and does not reproduce exactly what is seen and therefore is a form of camouflage detection if manipulated properly. The use of so called "false color" to both enhance the separation of objects and provide identification cues is represented by the two-and three-component camouflage detection films used. These exploit areas of the spectrum which are difficult to match with colorants. By recording these differences either on separate emulsions or by sequential filtering with a TV system and recombining them by superposition, each in a different color the result provides an exaggerated color difference cue not readily apparent to individual images before being combined. If this is done using separate cameras or otherwise recording narrow band images it is called "spectrozonal". The ultimate in this is to record the complete spectral distribution of each image point and selectively recombine whatever sets of spectral bands are desired.

Color is also used in a pseudo way to make completed patterns of data more comprehensible, without having any relationship to the data itself. The separation of a black and white image into a selected set of contrasts, and then coloring the contrast steps in different color permit an analysis not otherwise available. An example of this is the coloration of thermal images which show temperature - emissivity relationships through color differences. Another form involves applying arbitrary coloration to recorded phenomena such as atmospheric pressure differences or the common example of political divisions of a map.

The use of stereo techniques to achieve spatial separation of objects is well known today. The relationship is that of parallax separation versus overlap in the field of view of two sensor paths. By increasing the separation of image forming optics while keeping the scene overlapped (usually about 60%) as shown in Figure F-8, exaggeration in apparent depth is achieved. Optical range finders work on the same parallax basis. The ability to separate objects spatially has been used as a cue in discovering flat top camouflage screens which otherwise blended well. One would see a patch of terrain that for no apparent reason was floating above the ground. The use of drape screening systems, if installed properly, brings the terrain over the object in a hill-like fashion which is less likely to be noticed through the stereo technique.

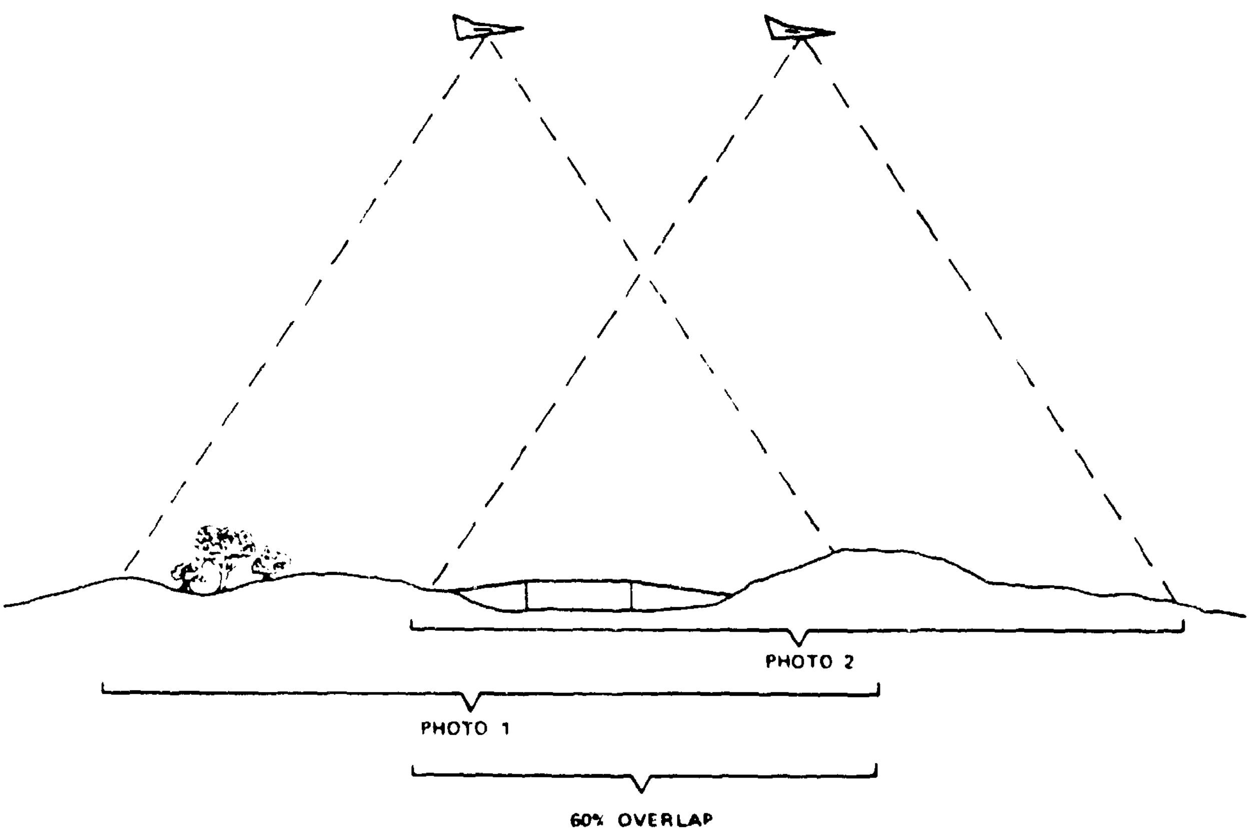


Figure F-8. Stereo Imagery Generation.

The technique of flickering alternate images of a given area or object to reveal differences is closely allied to the combination technique described in the discussion of color. It consists of alternately presenting to an observer first one, and then a second image. By optically superimposing these images of some scene taken at different times, any differences which have taken place are quickly revealed and a flickering is noted-- from whence it get its name. If a negative-positive combination is used and the light is balanced, that which has not changed will be cancelled out, and the detection cue is that only those objects which have been moved within, introduced to, or eliminated from, the scene will be evident.

Airborne surveillance systems employ unidirectional scanners which sweep a path below and normal to the direction of flight. The second dimension (that of the flight direction) is provided by the motion of the aircraft as shown in Figure F-9, so that the imagery produced is in continuous strip form. The ground pattern coverage shown in Figure F-7 for aerial photography also applies for IR systems.

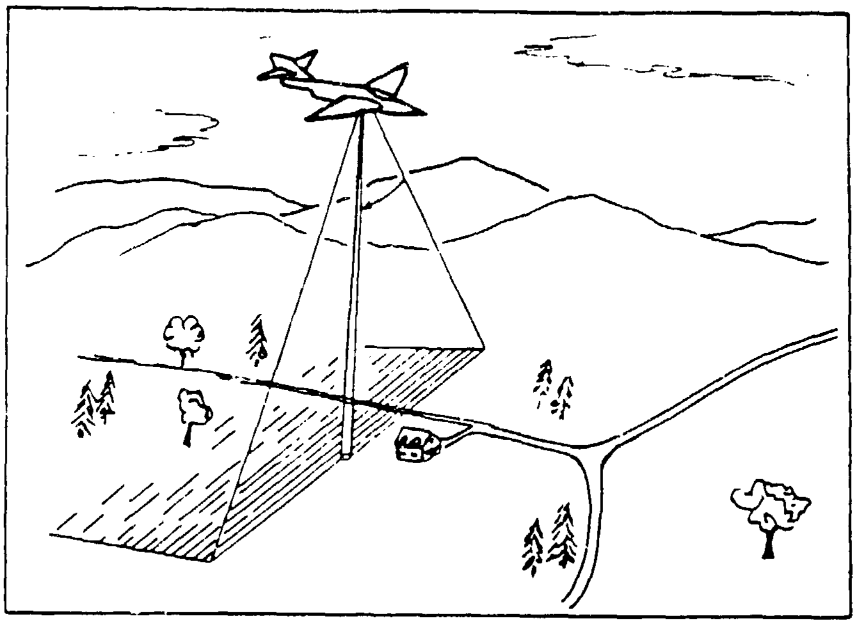


Figure F-9. Line Scanner Ground Coverage

Imagery can also be produced by two-dimensional or "raster"scanning. In this case, the image is time framed in a form similar to conventional television. Raster scanning systems for use aboard aircraft, ship, or vehicles have come to be known as downward - for forward-looking infrared systems (LIR or FLIR), while the unidirectional line scanner is simply called a line scanner. Both line scanners and DLIR's/FLIR's of today employ many detectors to effect greater scanning speeds.

F-5 THE 10-20 YEAR THREAT

F-5.1 Expected Trends and Organizational Changes.

Completed and potential camouflage advances will be recognized as efficient, effective measures to reduce RSTA productivity on the battlefield and to increase survivability and capabilities of friendly forces. Threat sensor capabilities are expected to expand in anticipation and response to the camouflage upgrades and to attempt to negate or degrade their effects.

The numbers and types of RSTA systems in tactical forces world-wide will increase. Greater emphasis will be placed on timely, versatile and well-integrated RSTA from the FEBA back to deep-strike depths of 100 km or more. The survivability of reconnaissance assets at all battlefield depths and comlinks that tie them together appear to be significant priorities in this future time period. New sensor technology, computer-assisted RSTA processes and new types of platforms for intelligence gathering have to be anticipated. Greater use of mobile, deep-recce units and advanced C^3I facilities will emphasize special purpose forces, air/sea force projection and high-skill personnel training in all tactical forces in the world.

Improved communications and signal processing/discrimination will retain recce responsibilities at every echelon from small units to corps. Direct real time communications among RSTA and combat organizations will undoubtedly influence the type and extent of air/ground operations toward greater activity, higher selectivity of targeting and greater accuracy/reliability of target intelligence.

More targets and higher targeting rates means greater demand for camouflage, cover and deception.

F-5.2 Ground Surveillance Radar.

The advantages of convenient size, lightweight mobility, all-weather operation and good resolution in both angle and range favor continued emphasis on radar as a principal RSTA sensor. Design trends are toward phased arrays, higher frequencies, frequency agility, complex waveforms and increased ECM/ECCM capabilities for the cluttered EM environments of future battlefields. Narrow beam widths, short pulse width and wide band capabilities with revolutionary digital signal processing, frequency and polarization diversity, and multiple-target detection and scanning characterize the emerging ground RSTA radar threat. Low-cost, low-power, highly reliable microcircuit electronics and efficient small antennas will stimulate proliferation of small, portable radar systems in forward battle areas.

Radar systems offer the best all-weather RSTA operation available. The higher mobility with smaller, lighter systems, especially phased arrays with much improved resolution and multi-frequency agility, will challenge current radar camouflage concepts. Higher frequencies (X-band and above) and narrower beams mean better target resolution. Combined with advanced microprocessors/digital signal processing, the detection capabilities and signature matching potential of these advanced radar systems for camouflage penetration is expected to be a significant threat.

F-5.3 Lasers.

The successful applications of IR lasers to range-finding assures further development of these sensors to exploit new solid state materials, detector focal plane arrays, microelectronic and microprocessing advances and emphasize passive devices with extensive signal processing enhancements. Multispectral track/scan and doppler lidar applications can be expected to upgrade target/camouflage detection and discrimination.

F-5.4 Television.

Near real time TV, including all-weather and night operations, will substantially increase active command use of visual imaging and man-portable TV systems with secure, high fidelity video links in the telecommunications networks. High resolution TV imaging based on VLSIC/VHSIC microelectronics/microprocessors, fiber optics comlinks, high-speed switching, image stabilization and display upgrades are certain to make some less sophisticated camouflage concepts obsolete.

F-5.5 Thermal Imaging.

Technologies in charge coupled device image processing and solid state focal plane arrays are currently beginning to enhance battlefield surveillance capabilities in both the 3-5 μw and 8-14 μw IR bands. Multi-sensor, multi-frequency technology integration is combining advances in detectors, optics, signal processors, displays and controls to produce new sensor architectures and substantially increased RSTA target detection/identification/location performance. Advanced thermal imaging systems may incorporate shared apertures, distributed massively-parallel processing, systolic arrays and perhaps neural networks to achieve fault tolerant, adaptive, microprocessor-controlled sensors with built-in data fusion that can seriously challenge current camouflage solutions.

F-5.6 Space Systems.

Military imagery resources allocated to battlefield RSTA remains quantitatively limited but qualitatively challenging to camouflage effectiveness. Photographic reconnaissance may lose its dominant role to near real time RSTA employing synthetic aperture radar, millimeter wave radar, focal plan IR and down-link TV systems. The C^3I integration of vastly improved digital RSTA systems is a threat to camouflage/concealment/deception (CCD) and is made possible by emerging computer-(microprocessor-) controlled network operations, distributed and parallel processing within the threat sensor systems operations and advanced ECM/ECCM capabilities in sensor/telecommunications interlinks. Near real time imaging RSTA systems with multi-sensor, all-weather, day-night, long-range coverage accurately fused with close-in, short-range RSTA is an idealized concept but its realization is, in fact, foreseeable and within technology capabilities in the 10-20 year time frame.

Hybrid space craft utilize Kn band from small Earth stations subsequently distribute video signals over great distances (e.g., at C-band to avoid weather interference) to TV receivers. Voice network applications rival F.O. cable capacities in integrated networks. Beyond mere telephone/TV are service applications such as

remote monitoring (e.g., security systems), fast access to distributed data bases (e.g., distributed intelligence for multispectral target profiles) and many other tailored applications of space-based systems.

Space sensor platforms may also participate in more static/bistatic target radiation scattering for RSTA. Complex scattering targets and multiple polarization target response may be susceptible to significantly enhanced SAR imaging performance for near real time or automatic target detection and classification.

F-5.7 Airborne RSTA.

The proliferation of airborne RSTA capabilities at all threat levels of fixed wing aircraft and helicopter platforms intensifies the camouflage threat to all types of tactical targets. Individual sensor capabilities are rapidly incorporating technology advances that specifically enhance RSTA using IR fast-scanners, real-time TV and video data links, SLAR/SAR, MMW and photoreconnaissance. RSTA systems will benefit from technology advances in each area to reduce size/weight, increase resolution and contrast discrimination, overcome clutter and environment limitations and expand data processing speed/volume by orders of magnitude. Multi-sensor imagery, near-real-time whether from FLIR, SLAR, SAR or photoreconnaissance represents new demands on camouflage technology.

Camouflage techniques face a greatly enhanced airborne threat from short-range, low-altitude RSAT from helicopter and RPV/drone platforms using these same emerging technology applications in even greater numbers and tactically dangerous encounters.

Aircraft trends toward specialized, highly capable RSTA such as bi-static SLAR/SAR, real-time target data processing and down link communication to weapons platforms presage an all-weather, day-night target threat whenever such aircraft become available. Helicopter exploitation of heads-up displays (HUDs) can, for example, double the detection range against tanks and other high-value targets. RPVs/drones are expected to exploit technology size/weight reductions and on-board computer processors to combine real-time electro-optical/IR/SIGINT capabilities against camouflaged targets anywhere on the battlefield. High-resolution, fast-scan FLIR systems for real-time RSTA with possible networking with ground RSTA to pinpoint targets are already in the RSTA technology base world-wide. Added capabilities here may involve new laser designators for surprise short-pulse attacks by airborne weapon platforms.

Applications of MMW, multicolor IR, laser and MW radar techniques to smart weapons and homing submunitions against camouflaged targets are expected threats. The exploitation of MMW at all waveband frequencies will extend the vulnerability envelopes of all tactical targets and present serious RSTA threat problems to camouflage planners.

F-5.8 Millimeter Wave Sensors.

Dominant frequencies for millimeter wave radar sensors correspond to the environment windows 35-40 GHz, 94-95 GHz, 140 GHz and other higher frequencies out to 300 GHz and beyond. Here, the digital signal processing has great impact for MTI capabilities, frequency/polarization diversity and resistance to environmental interference.

Millimeter wave sensors, inherently smaller than their lower frequency cousins, have great advantages for tactical use, ground and air. The enhanced information content of large bandwidth MMW signals along with higher pulse power levels will provide much higher resolution and signal amplitudes for accurate recognition/location of targets in RSTA applications. Low weight, small size and very large digital signal processing capacities can lead to extremely capable imaging and target discrimination functions that will stress the camouflage technologies to hide, blend or disguise RSTA targets.

Since MMW will find many other military uses such as terrain tracking/ avoidance, drone-mounted SLAR/SAR, and missile guidance applications, it is likely that multi-mode applications for tactical RSTA will appear at the same time. There is world-wide interest in MMW for smart submunitions as well as smart target sensors and combined multi-sensor MMW/IR, MMW active/passive, MMW high pulse power devices and exploitation of sub-MMW regions of the spectrum beyond 140-300 GHz. These developments present difficult challenges to camouflage technology.

F-5.9 RPV/Drone Platforms.

Advantages of future RPV/drone platforms for performing RSTA functions on the battlefield are well recognized. active development programs in the U.S. and elsewhere are evaluating RPV/drones for fire support, electronic countermeasures and observation. In part, the RPV/drone interests derive from the postulated operational environments described in Army 21/AirLand Battle 2000 concepts. The future battlefield threat will be populated by combat vehicles (and forces) with speed and agility, by weapon systems with great range and even greater lethality and by improved intelligence-gathering RSTA sensor systems with high capable data processing. Threat forces on both sides may deploy a broad spectrum of sophisticated RSTA in the air (aircraft, helicopters and RPV) and on the ground.

RPV/drones offer the RSTA close-up views as well as differentiating of enemy forces/systems. The differentiated views of the targets substantially increase the available information about those targets and the close-up observations allow the RSTA sensors to gain the advantage of short range and large signals.

F-5.10 Reaction to Camouflage.

Modern perceptions of the vital role of RSTA in collecting, analyzing and distributing tactical and operational intelligence tend to draw attention to any and all means developed to camouflage targets in the field. Larger numbers of sensors are expected at all echelons on the battlefield and in every intensity level of combat. This increases RSTA/target encounter likelihood and assures multiple looks at every point of interest. Technical sophistication to provide broader spectral coverage, multispectral sensor systems, and integrated RSTA operations to obtain real time multi-sensor intelligence can provide necessary countermeasure actions. Such actions can be expected to respond to U.S. emerging technologies, camouflage techniques and methods, and deployed camouflage equipment.

Spread of advanced technology from Western nations to potential U.S. adversaries is evident in nearly every significant RSTA sector. Sophisticated reconnaissance sensors (visual aids, electro-optical devices, microwave/MMW radar, lasers and SIGINT)

are being transferred from the West and, in some cases (e.g., sensor materials, microchips, image intensifiers), the technology for advanced RSTA has been made available to large number of foreign producers who are not necessarily monitoring or restricting further transfer of these technologies world-wide.

Depending on the U.S. effort to continuously improve, enhance and upgrade camouflage techniques and methods, the foreign reaction to these programs may or may not increase the marginal advantage in camouflage, concealment and deception presently existing in relation to potential threats. Technology advancement in each of the significant camouflage concept areas and techniques noted in this Guide will determine future survivability and effectiveness of U.S. combat forces subjected to RSTA systems of the adversaries.

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